H. FOSTER BAIN.

REPORT OF

THE BUREAU OF MINES, 1905

VOL. XIV. PART I.

CONTENTS

PRINTED BY ORDER OF THE LEGISLATIVE ASSEMBLY OF ONTARIO

TORONTO:
Printed and Published by L. K. CAMERON, Printer to the King's Most Excellent Majesty
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Toronto.

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LIST OF ILLUSTRATIONS

To His Honor William Mortimer Clark, Etc., Etc., Etc.,

Lieutenant-Governor of the Province of Ontario.

Sir,—I have the honor to transmit herewith for presentation to the Legislative Assembly, the Fourteenth Report of the Bureau of Mines.

I have the honor to be, Sir,

Your obedient servant,

J. J. Foy,

Commissioner of Crown Lands.

Department of Crown Lands,
Toronto, 6th April, 1905.

To the Honorable James Joseph Foy,

Commissioner of Crown Lands.

Sir,—I beg to submit to you herewith, to be presented to His Honor the Lieutenant-Governor, the Fourteenth Annual Report of the Bureau of Mines.

The Report consists of three parts, which are printed separately, namely:

Part I., containing statistics of the mineral production of the Province for the year 1904, reports by the Inspectors of Mines on the working mines of Western and Eastern Ontario, papers on Petroleum and Natural Gas, and the Cement Industry of the Province, reports of exploration parties on special mineral districts, and other information relating to the mineral resources and mining industries of the Province.

Part II., a description of the silver-cobalt-nickel ores of Lake Temiskaming, by Prof. W. G. Miller, Provincial Geologist, supplementary to the account published in the Bureau's Thirteenth Report.

Part III., a monograph on the Sudbury Nickel Region by Dr. A. P. Coleman, who spent the field seasons of 1902, 1903 and 1904 in the nickel district, and whose description covers the whole of that important mineral area, including both the southern and northern ranges.

All three Parts are accompanied by geological and other maps illustrating the territory and subjects dealt with.

I have the honor to be, Sir,

Your obedient servant,

Thos. W. Gibson,

Director.

Office of the Bureau of Mines,

Toronto, 5th April, 1905.

REPORT OF
THE BUREAU OF MINES
1905

Vol XIV **Part I**

By Thos. W. Gibson, Director

Statistical Review

Table I summarizes the output of the mines and metallurgical works of the Province of Ontario for the calendar year 1904. It will be seen that the total value is $11,572,647, a decrease as compared with 1903 of $1,297,946, mainly accounted for by the diminished yield of the nickel field, where one of the plants was closed for part of the year, and the other was being rebuilt on a larger and more modern scale.

Table I.—Mineral Production of Ontario 1904

Product.	Quantity.	Value.	Employees.	Wages.
Metallic :		$		$
Gold....ounces	2,285	40,000	210	128,000
Silver.... "	206,875	111,887		
Platinum.... "	536	10,452		
Palladium.... "	952	18,564		
Cobalt....Tons	29	36,620	1,063	570,900
Copper.... "	2,163	297,126		
Nickel.... "	4,743	1,516,747		
Iron Ore.... "	53,253	108,068	191	84,673
Pig Iron.... "	127,845	1,811,664		
Steel.... "	51,002	1,188,349	1,522	539,482
Lead Ore.... "	3,210	11,000		
Pig Lead.... "	43	2,500	16	6,000
Zinc Ore.... "	533	3,700	15	5,712
		5,156,677	3,017	1,334,767
Less value Ontario ore smelted into pig iron, Ontario pig iron converted into steel, and lead ore smelted into pig lead....	....	250,000		
Net metallic production....	....	4,906,677	2,807	1,334,767
Non-metallic:				
Actinolite....tons	408	102	....	....
Arsenic.... "	72	903	....	....
Tile, drain....number	16,000,000	210,000	3,000	660,000
Brick, common.... "	200,000,000	1,430,000		
" paving.... "	4,436,000	55,450	67	27,300
" pressed.... "	26,857,000	226,750	217	101,530
Building and crushed stone....	....	700,000	1,440	510,186
Carbide of calcium....tons	2,343	152,295	78	35,200
Cement, natural rock....bbls	85,000	65,250	60	22,050
" Portland.... "	880,871	1,239,971	734	323,689
Corundum....tons	1,665	150 645	202	139,548
Feldspar.... "	10,983	21,966	34	16,300
Graphite.... "	355	4,700	52	11,925
Gypsum.... "	5,412	10,674	14	6,000
Iron Pyrites.... "	13,451	43,716	60	22,875
Lime....bush	2,600,000	406,800	500	150,000
Mica....tons	332	37,847	79	21,529
Natural Gas....	....	253,524	98	53,674
Peat Fuel....tons	800	2,400	10	2,000
Petroleum....Imp. gals	17,237,220	904,437	406	229,955
Pottery....	....	100,000	100	30,000
Salt....tons	55,877	362,621	193	84,682
Sewer Pipe....	....	283,000	113	54,500
Talc....tons	1,313	2,919	17	873
Total Non-Metallic production....	....	6,665,970	7,474	2,503,816
Add Metallic production....	....	4,906,677	3,017	1,334,767
Total production....	....	11,572,647	10,491	3,838,583

A comparison of the foregoing table with those given in former years will disclose the fact that the mineral products of Ontario, already numerous and varied, are growing steadily in number and variety. Three metals find a place in the output of 1904 which were wanting in 1903, namely platinum, palladium and cobalt. The first two of these are new entrants, and are to be credited to the Sudbury nickel field, from the mattes of which they are obtained as bye-products. Further comment is made on these metals on a later page. The third, cobalt, does not make it first appearance in 1904, but has been absent from the list since 1894. Like the other two it is found in the nickeliferous pyrrhotite, but until last year no returns of its recovery were received at the Bureau since the Dominion Mineral Company ceased operations some ten years ago. But a much more prolific source of cobalt has been opened up in the silver-cobalt-nickel-arsenic veins of Coleman township, whose riches in silver and cobalt stamp the discovery of these deposits as one of the most important events in the history of the mining industry of Ontario, or indeed in that of the Dominion.

The following columns show clearly how this expansion in the variety of the mineral products of the Province has gone on during the 10-year period from 1895 to 1904.

Metals

	1895 $	1904 $
Silver	nil	111,887
Platinum	nil	10,452
Palladium	nil	18,564
Cobalt	nil	36,620
Iron Ore	nil	108,068
Pig Iron	nil	1,811,664
Steel	nil	1,188,349
Lead Ore	nil	11,000
Pig Lead	nil	2,500
Zinc Ore	nil	3,700

Non-Metals

Actinolite	nil	102
Arsenic	nil	903
Carbide of Calcium	nil	152,295
Corundum	nil	150,645
Feldspar	nil	21,966
Graphite	nil	4,700
Iron Pyrites	nil	43,716
Talc	nil	2,919

Thus, ten metallic and eight non-metallic substances find a place in the output of 1904 which were lacking in 1895, only some four or five of which, such as silver, cobalt, iron ore and pig iron had ever before been raised or produced in the Province.

The total number of substances combining to make up the mineral production of Ontario is thirty-seven, ten of which may be classed as construction materials. A comparison with our sister mining Provinces, Nova Scotia and British Columbia, in this respect, shows that in the official tables of the former, eleven products and in the latter, six, exclusive of the building materials, make up the list. In each case coal and gold constitute a large part of the output. This brief reference will make it plain how different are the conditions of the mining industry here from those surrounding it on the Atlantic and Pacific coasts, and will also convey some idea of the difficulties attending the endeavor to procure correct and complete statistics of the mineral production of this Province.

Table II is a comparative schedule giving the value of the several mineral products for the last five years, and enables the progress of the various departments of the industry to be traced from year to year.

Table II.—Mineral Production 1900 to 1904

Product.	1900.	1901.	1902.	1903.	1904.
	$	$	$	$	$
Metallic:					
Gold	297,861	244,443	229,828	188,036	40,000
Silver	96,367	84,830	58,000	8,949	111,887
Platinum	....	....	....	....	10,452
Palladium	....	....	....	....	18,564
Cobalt	....	....	....	....	36,620
Copper	319,681	589,080	680,283	716,726	297,126
Nickel	756,626	1,859,970	2,210,961	2,499,068	1,516,747
Iron Ore	111,805	174,428	518,445	450,099	108,068
Pig Iron	936,066	1,701,703	1,683,051	1,491,696	1,811,664
Steel	46,380	347,280	1,610,031	304,580	1,188,349
Lead Ore	....	....	....	....	11,000
Pig Lead	....	....	....	1,500	2,500
Molybdenite	....	....	400	1,275	....
Zinc Ore	500	15,000	11,500	17,000	3,700
	2,565,286	5,016,734	7,002,499	5,678,929	5,321,677
Less value Ontario ore smelted into pig iron, and pig iron converted into steel	....	....	745,000	436,354	250,000
Total metallic production	2,565,286	5,016,734	6,257,499	5,242,575	4,906,677
Non-Metallic:					
Actinolite	....	3,126	6,150	1,650	102
Arsenic	22,725	41,677	48,000	15,420	903
Brick, common	1,379,590	1,530,460	1,411,000	1,561,700	1,430,000
Brick, paving	26,950	37,000	42,000	45,288	55,450
" pressed	114,419	104,394	144,171	218,550	226,750
Building and crushed stone	650,342	850,000	1,020,000	845,000	700,000
Carbide of Calcium	60,300	168,792	89,420	144,000	152,295
Cement, natural rock	99,994	107,625	50,795	69,319	65,250
" Portland	598,021	563,255	916,221	1,182,799	1,239,971
Corundum	6,000	53,115	83,871	87,600	150,645
Feldspar	5,000	6,375	12,875	20,046	21,966
Graphite	27,030	20,000	17,868	20,636	4,700
Gypsum	18,050	13,400	19,149	7,910	10,674
Iron Pyrites	....	17,500	14,993	21,693	43,716
Lime	544,000	550,000	617,000	520,000	406,800
Mica	91,750	39,780	102,500	102,205	37,847
Natural Gas	392,823	342,183	199,238	196,535	253,524
Peat Fuel	....	....	....	3,300	2,400
Petroleum products	1,869,045	1,467,940	1,431,054	1,586,674	904,437
Pottery	157,449	193,950	171,315	160,000	100,000
Salt	324,477	323,058	344,620	388,097	362,621
Sewer pipe	130,635	147,948	191,965	199,971	283,000
Talc	5,000	1,400	930	2,625	2,919
Tile, drain	209,738	231,374	199,000	227,000	210,000
Total non-metallic production	6,733,338	6,814,352	7,134,135	7,628,018	6,665,970
Add metallic production	2,565,286	5,016,734	6,257,499	5,242,575	4,906,677
Total production	9,298,624	11,831,086	13,391,634	12,870,593	11,572,647

GOLD

Dealing briefly with the figures of the several products as given in Tables I and II, it is first to be remarked that the yield of gold has again suffered a heavy decline as compared with the previous year, when the production was smaller than in 1902. The greatest output of gold in this Province was in 1899, when it had a value of $424,568. This was when the excitement in the Lake of the Woods and Rainy Lake regions had led to the erection and operation of a large number of stamp mills to test the auriferous quartz veins of those districts. In many cases results not being up to expectations, and in others funds raised by the sale of non-assessable stock having been exhausted before the mine was placed on a paying basis, the outcome of the venture was the closing down and virtual abandonment of the property. Too often the result was brought about or hastened by the incompetency, or worse, of the management.

Bullion was produced last year in an experimental way at half-a-dozen properties on Lake of the Woods, Eagle lake and elsewhere, and on a slightly larger scale at the Sultana, Sunbeam (or A L 282) and St. Anthony Reef mines, while a good deal of

development work was carried on not only at the properties mentioned, but also at the Laurentian and Volcanic Reef mines on lake Manitou, at the Golden Horn on Rush bay, by the Northern Light Mines Company, the Camp Bay Mining Company, the Eldorado Mining Company and others.

In eastern Ontario, the only gold actually obtained was by the Cook Land Company, near Marmora. Belmont and Deloro were idle, but there are hopes of resuming work at both places. The Craig mine is being re-opened, and a new property, the Star of the East in Barrie township, is under development. For the first time returns were made of the recovery of small quantities of gold and silver from the mattes of the Sudbury nickel district. Some attention is being paid to the placer ground on the upper Vermilion river, with the view of putting a dredge at work if the gold found in the immense gravel deposits of that region is ascertained to be present in payable quantity.

The output of gold and other details of the industry for the last five years are given in the following table:

Gold Mining 1900 to 1904

Schedule	1900	1901	1902	1903	1904
Mines worked .... No.	18	11	20	19	12
Ore treated .... tons.	46,618	54,336	48,544	32,347	....
Gold product .... oz.	18,767	14,293	13,625	10,383	2,285
Gold value .... $	297,861	244,443	229,828	188,036	40,000
Men above ground .... No.	412	305	341	243	100
" under ground .... "	338	288	385	250	130
Wages paid .... $	350,694	287,409	343,984	245,490	133,000

SILVER

Hitherto, practically all of the silver produced in Ontario has come from the lake Superior region. The typical mine of this district was Silver Islet, a tiny rock lying off a bold peninsula now forming the Sibley township forest reserve, where Thomas Macfarlane in 1868 discovered silver ore rich in large nuggets and smaller disseminated particles, and whence by working with crowbars under the water he obtained the first shipment of 1,336 lb. of ore, the assay of which was 2,087 ounces Troy per long ton. From first to last about $3,500,000 worth of silver was extracted from Silver Islet mine.[1]

The rich veins of this mine and of other valuable silver mines which were opened up at a later date in the district west of Port Arthur, in an area of similar geological features, traversed the slates of the Animikie formation, and this fact is of interest in relation to the latest of the silver fields of this Province, that now being energetically developed in the township of Coleman on the Temiskaming and Northern Ontario Railway. Here the lodes occur in the slate breccia, and so far have not been found either lying in or extending downwards into any of the associated or underlying formations. It is noticeable, too, that to a marked extent the assemblage of minerals is similar, including cobalt, nickel and arsenic, though the development of these in Coleman appears to be greater than it was in Silver Islet. The veins are narrow, but exceedingly rich, and the aggregate output of the properties, from present appearances, may easily equal if not surpass in value the yield of Silver Islet, notwithstanding that the price of silver now is less than half what it was 25 or 30 years ago.

1 *See* the Story of Silver Islet Sixth Rep. R. of M. pp. 125-158. Mr. Macfarlane, one of the band of early geologists, which included also Logan, Hunt, Murray and Bell, that did such yeoman service in laying the foundations of Canadian geology, is like the last mentioned, still in harness, though having transferred his allegiance from geology to chemistry. Mr. Macfarlane now fills the position of Chief Analyst to the Department of the Interior, Ottawa.

All the silver produced in 1904 came from the mines of Coleman township, save a small quantity extracted from the Sudbury nickel-copper mattes. The output was 206,875 ounces, valued at $111,887. The producing properties were the Larose, owned by Messrs. Timmins, Dunlap and McMartin; the Chambers-Ferland properties, including Cobalt Hill and the Little Silver mine, now owned by the Nipissing Mining Company, Limited, New York, of which Mr. Ellis P. Earle is the head; the New Ontario owned by Mr. W. G. Trethewey of Toronto; and the McKinley-Darragh, of which Messrs. Gorman & Co. of Ottawa, otherwise the Cobalt and Silver Mining Company, are proprietors. The ore was all sold to Mr. E. P. Earle and delivered to him at New York. Some of the shipments carried very high values, several 20-ton carlots netting as much as $37,000 or $38,000, the main returns being from the silver, though the other constituents, cobalt, nickel and arsenic, each contributed to the result. Production has been going on at an increasing rate since the close of the year, and for the first six months of 1905 the ore shipped yielded 1,128,212 ounces of silver, valued at $595,974. Several other properties have also been opened up in 1905 from some of which shipments have been made.

The new camp enjoys first-rate shipping facilities, since the Temiskaming and Northern Ontario Railway runs directly through it, and a station called Cobalt has been established on the shore of a lake of the same name within easy distance of the chief producing properties. The freight rate from Cobalt to New York is $7 per ton.

For a fuller account of the geology and mineralogy of this interesting and important field, reference should be had to the report of Prof. W. G. Miller, Provincial Geologist, published as Part II. The geological map of the area accompanying the report was issued in advance, and has been in active demand from prospectors and others.

Considerable prospecting was done in the neighborhood of the original finds during the season of 1904, and several fresh discoveries were made, but so far no new fields of like kind have been located in the extensive regions of slate conglomerate in the neighborhood of lake Temagami and on the Montreal river. A great deal of the territory is covered by green timber, including much valuable pine, consequently prospecting must be carried on carefully, and is slow and tedious work.

Silver Mining 1900 to 1904

Schedule		1900	1901	1902	1903	1904
Ore raised	tons.	12,500	11,000	6,250	3,400	158
Ore stamped	"	8,000	7,560	6,250	3,360	158
Bullion product	oz.	160,612	151,400	96 666	16,688	206,875
Value of bullion	$	96,367	84,830	58,000	8,949	111,887
Average men above ground	No.	20	30	25	12	29
" " under ground	"	30	35	25	20	28
Wages paid for labor	$	24,000	29,500	36,000	8,000	12,300

PLATINUM

It has long been known that platinum occurs in association with the nickel-copper ores of the Sudbury region, mainly, it is believed, as the arsenide sperrylite, so called after Mr. F. L. Sperry, who in 1889 first isolated it from the gossan of the Vermilion mine.[2] It is also found in the ore of the Victoria, Copper Cliff and other mines of the region, varying from almost inappreciable quantities up to 3 dwt. and even over 7 dwt. per ton of ore, in proportion, apparently, to the percentage of chalcopyrite present. But the fact that platinum has been recovered from Sudbury ores as part of their commercial treatment has only recently been made public, and the successful extraction of quantities so minute is a tribute to the perfection at which modern metallur-

[2] 1st Rep. B. of M. pp. 91, 92; also 7th Rep. p. 142, 12th Rep. pp 272, 282, 283; and other references.

gical processes have arrived. By far the greater portion of the world's supply of platinum is derived from alluvial deposits, the Ural mountains in Russia being the chief source, but it is found also in New South Wales, California, British Columbia, the Yukon, and many other parts of the world, in association with placer gold. It can probably be claimed that Ontario furnishes the first instance of solid ore being regularly treated for the recovery of platinum.

The yield of this rare metal for 1904 is returned at 536 ounces, which at $19.50 per ounce, had a value of $10,452. In 1902 and 1903 the quantities obtained were considerably larger, being for the former year 2,375 ounces, and for the latter 1,710 per ounce, had a value of $10,452. In 1902 and 1903 the quantities obtained were considerably larger, being for the former year 2,375 ounces and for the latter 1,710 ounces, of the value, at the above price per ounce, of $46,312 and $33,345 respectively. The yield of platinum, therefore, from the ores of the Sudbury district for the last three years, before which little or none was obtained, was as follows:

	Quantity ounces	Value $
1902	2,375	46,312
1903		33,345
1904	536	10,452
Total	4,621	$90,109

The above quantities were recovered, not only from the mattes treated during the respective years, but also from the residues or accumulations of several years, so that no data exist for estimating the tonnage of the ore from which they were taken, or how much was obtained from the matte in any one year. It is stated, and no doubt correctly, that if the mattes had to be treated solely for the purpose of winning the platinum and other bye-product metals—details of the production of which are given under their respective headings—the process would be an unprofitable one, and they would not be recovered at all, but as very much of the manipulation is necessary for extracting the nickel and copper, which provide the chief values, the subsidiary metals, comprising gold, silver, platinum, palladium and cobalt, can be obtained at a profit.

The prospects of the Sudbury ores furnishing a steady supply of platinum from this time forward are however not hopeful, for the reason that until the last year or two most of the ore raised by the principal producer, the Canadian Copper Company, came from the Copper Cliff group of mines rich in copper, but somewhat less rich in nickel, while now almost the whole of the ore smelted by that Company is taken from the Creighton mine, which is unusually high in nickel, but comparatively low in copper. As the platinum appears for the most part to bear company with the copper, the yield may be expected to be small, so long as the Creighton ore continues to be exclusively used. It may be added, as illustrating the comparative scarcity of platinum, that in British Columbia, the only other Province in Canada yielding this metal, the quantity obtained last year was only 35 ounces.

PALLADIUM

Palladium is another of the rarer metals which appears on the list of Ontario productions for the first time in 1904. Its source is also in the nickeliferous pyrrhotites of Sudbury—those remarkable ores from which no less than seven different metals are obtained: nickel, copper, cobalt, gold, silver, platinum and palladium, and from which two other useful substances, one a metal and the other a non-metal, namely iron and sulphur, are eliminated only to be wasted. The announcement that palladium was being obtained by the Orford Copper Company at its New Jersey works from Sudbury matte was made by Dr. Joseph Wharton, Sc. D., LL.D., in an address delivered in April, 1904, before the American Philosophical Society, and published in Vol. XLIII of the Proceedings of that body. Dr. Wharton points out that although

palladium belongs to the platinum group of metals, it is in some respects nearly related also to silver, its atomic weight and specific gravity being respectively about 107 and 11.4, while the corresponding figures for silver are 108 and 10.5. In its high melting point, however, of 1500°C., it approaches more nearly to platinum, which melts at 1750°C., and in color its grayish-white resembles the color of platinum more nearly than that of silver. He adds:

"Palladium has long been known to occur native in company with platinum, and also alloyed with gold in the Brazilian mineral porpezite, which contains about 5 to 10 per cent. of it. That it occurs in notable quantity in the nickeliferous pyrrhotite of Canada is an important recent observation. Both platinum and palladium probably exist to a greater or less extent in all the many deposits of nickeliferous pyrrhotite throughout the world; certainly in those of Norway and Sweden, and particularly in every one of the numerous deposits of that mineral which are found in the Laurentian and Huronian rocks surrounding the little town Sudbury, in the Province of Ontario, Canada. The quantity, however, is extremely small, varying from a mere trace to one or more ounces per ton; the average for each metal being about one hundredth of an ounce per ton of ore, platinum and palladium usually being present in approximately equal parts. Yet, though known to exist in many parts of the world, palladium has not been diligently sought for, because there was until recently no considerable demand for it; the re-working of platiniferous residues from the mints of several countries having supplied most of that which appeared in commerce. The prevailing scarcity of platinum is now directing attention to palladium as a practicable substitute for some purposes . . . . . . The form in which palladium there [*i. e.* in the Sudbury ores] occurs has not been detected, for owing to its minute quantity and the consequent difficulty of isolating it, none has yet been directly observed in any ore of that region; since, however, platinum occurs there as arsenide in the interesting mineral sperrylite (PtAs2), palladium may exist in similar combination, though none has been observed in any specimen of sperrylite that has been examined"

The uses of palladium are enumerated by Dr. Wharton as follows:

"1. For the mechanism of delicate instruments, such as chronometers, and for verniers, etc., of astronomical instruments.

"2. For surgical instruments.

"3. For plating searchlight mirrors. Why not for the mirrors of reflecting telescopes?

"4. For alloying with silver to make dental plates, etc., instead of the two-thirds silver one-third platinum hitherto used in Europe. Also as palladium amalagam for fillings in cavities of teeth.

"Other uses will naturally arise as men's minds are turned toward this metal which, while in many respects equal to platinum, sells for no more than the price by weight of that metal, and of course therefore for much less than that by bulk; the specific gravity of platinum being variously stated as 17 to 19, and that of palladium as 11.4 to 11.8. It would seem that palladium might be useful under some circumstances for resistance wire."

An interesting general description of the method of obtaining palladium from the matte is given by Dr. Wharton, though, as he states, he purposely refrains from giving all details of the various stages of the process. He says:

"The concentrated matte is treated for separation of copper from nickel, which is effected by repeated melting with nitre cake and coke in cupola furnaces. The coke converts the nitre cake into sodium sulphide; when the charge is run out of the furnace and cooled it separates easily into two parts, the bottoms containing practically all the nickel, the tops consisting of sodium sulphide and copper sulphide; the gold and silver going with the tops, the platinum-group metals going with the bottoms. In the refining processes that follow, palladium is obtained as a slime, carrying about a thousand times as much palladium proportionally as did the original ore, carrying also the other platinum-group metals, and the gold and silver. This palladium-bearing slime is melted and refined in a small reverberatory furnace, from which it is ladled out into cold water, forming shot which are charged into small leaden towers, into the top of which hot dilute sulphuric acid is run. Palladium and the other precious metals being electro-negative to the base metals, a galvanic action now takes place in which nickel, copper and iron dissolve rapidly, leaving palladium in a black mud containing two per cent. or more of that metal. If this residue still contains much copper, that is mostly eliminated by further treatment with hot sulphuric acid until the stuff contains about 25 per cent. of palladium, when it is treated with aqua-regia, thus

dissolving all the platinum, palladium and gold. From this solution platinum is precipitated by ammonium chloride. The palladium in the filtrate is electrolytically precipitated with a platinum anode, appearing as a dull gray metal which is hard and brittle, peeling off easily from the cathode. It is then dried and ignited in a reducing atmosphere, when it takes great brilliancy and becomes very soft and pliable, capable of being worked into any ordinary form. I have, for instance, a remarkably nice teaspoon made of it."

In further exposition of the properties of palladium, Dr. Wharton asserts that besides having so very high a melting point, and being at the same time both hard, ductile and malleable, palladium is so absolutely non-corrodible that a sheet of it may hang for a long time in a laboratory exposed to chlorine and hydrogen-sulphide gases without losing its polish or being tarnished. He also comments upon its wonderful power of occluding hydrogen gas, being capable of absorbing as much as 1,030 volumes, at which point complete saturation is probably reached. In the occlusion of hydrogen, palladium exhibits its affiinity to platinum, which possesses a similar property, but in a less degree.

Regarding the quantity of palladium produced, Dr. Wharton states that there is now a steady production by the Orford Copper Company of more than 3,000 ounces annually, from approximately 300,000 tons of Canadian ores treated. According to the returns made to this Bureau, the production for 1904 was on a much smaller scale, being 952 ounces, which valued at $19.50 per ounce, the same price as for platinum, was worth $18,564. During 1902 and 1903, however, the output exceeded Dr. Wharton's figures, as shown in the following table:

	Quantity ounces	Value $
1902	4,411	86,014
1903	3,177	61,952
1904	952	18,564
Total	8,540	$166,530

Palladium as well as platinum is found in British Columbia, the report of the Consolidated Cariboo Hydraulic Mining Company, Limited, for 1904, showing that the heavy concentrates remaining in the sluices after cleaning up yielded on analysis 61.4 ounces of palladium per ton, as well as 64 ounces of platinum and 42 ounces of osmiridium. The platinum, palladium and osmiridium were found as minute metallic grains and enclosed in small fragments and nuggets of magnetite and chromite. The gold, silver and copper contents of these concentrates brought the total value up to $5,993.56 per ton.[3]

COBALT

As already stated, the last production of cobalt from Ontario ores reported to the Bureau previous to 1904 was in 1894, when some 3¼ tons were returned, valued at $1,500. Inclusive of 1894 the total output up to that time appears to have been 30¾ tons, worth $14,613. In 1904 the yield was 29 tons, worth $36,620. This came from two sources: (1) the nickel-bearing ores of the Sudbury region, and (2) the silver-cobalt-nickel-arsenides of Coleman township, already referred to under the heading of silver, the latter producing a little more than half. As in the case of platinum and palladium, cobalt has been obtained in refining the Sudbury mattes for the last three years, the total quantity obtained in this time being a little over 32 tons. The material treated during this period consisted for the most part of the concentrated matte made at the Ontario Smelting Works by crushing, calcining and re-smelting the ordinary or low-grade mattes produced at the Copper Cliff smelters, and doubtless residues from mattes of the same kind previously treated for nickel and copper. In re-modelling and modernizing the smelting works at Copper Cliff after the Ontario plant was destroyed by fire, Bessemer converters were substituted for the Brown calciners, and

[3] Company's Seventh Annual Report, published in The Mining Record, Victoria, B.C., March, 1905.

in the process of converting the low-grade into high-grade matte in the Bessemer converters, practically all of the cobalt is blown out and wasted; since this metal oxidizes in the early stages of the blowing process, along with the iron, leaving the nickel and copper in the matte. As both the Canadian Copper Company and the Mond Nickel Company now produce Bessemer matte exclusively, the production of cobalt from the Sudbury ores is likely, for the time being at least, to cease. The fact that the cobalt is lost in the Bessemer process does not prove that process to be an uneconomical one, since its other advantages from a monetary point of view are more than sufficient to counterbalance the loss in this respect.

The extinction of this source of supply of cobalt, however, by no means implies the disappearance of cobalt from the list of minerals produced in Ontario. Indeed, the new resources of this metal now being exploited in Coleman township are of much greater extent and value as a source of cobalt than the pyrrhotites of Sudbury, in which it is present in small percentages only. The ores of Coleman are no doubt the richest ores of cobalt now being mined anywhere, containing as they do up to 18 per cent. of the metal. Shipments from Cobalt station during the first six months of 1905 contained a total of 65 t ns of cobalt, valued at $80,560. The gross weight of the ore was 891 tons, the average cobalt contents being thus 7.3 per cent.

It is not a little curious—yet considering the natural affinities of the two metals, not surprising—that as Ontario has wrested the supremacy from the island colony of New Caledonia in the production of nickel, so also is it now bidding fair to accomplish the same result in the production of cobalt. In fact, it may almost be said that it has already done so, since the price of cobalt which in the Bulletin du Commerce, published in Noumea, New Caledonia, was quoted in October, 1904, at 150 to 160 francs per ton (2,240 lb.) for ore containing 4 per cent. cobalt, had in March 1905, after regular shipments from the Coleman veins had begun, fallen to 100 to 125 francs. Nor is this to be wondered at, when the ores are compared, the New Caledonia product carrying 4 or 5 per cent. cobalt and the Ontario ore 16 or 18 per cent., to say nothing of the other constituents, silver, nickel and arsenic. The price which the cobalt miners in Coleman receive for their output in New York is about 65 cents per lb. of cobalt contents, or say $195 per ton (2,000 lb.) of 15 per cent. ore, which compares with $29 per ton for 4 per cent. ore in New Caledonia in October, 1904, or $22 in March, 1905.

There is no guarantee, of course, beyond existing contracts, that these prices for Ontario ore will be maintained. The demand for cobalt is a limited one, which only new uses for the metal or its compounds can materially extend; and should there be a greater production at any time than the market can absorb, the result must be that prices will fall. Fortunately for the mine-owners of Coleman, the majority of the deposits are worked chiefly for their silver contents, cobalt being largely a bye-product, consequently this metal could sustain a severe fall in price without materially affecting the prosperity of the camp or the value of the mines. There are, however, one or two deposits which yield cobalt with little or no silver.

The working properties during 1904 are the same as those enumerated under the heading of Silver, and for greater detail the reader is referred to the report of the Provincial Geologist.

NICKEL AND COPPER

As compared with 1903 the output of nickel was less in quantity by 2,255 tons, and in value by $982,321. The falling off has been already explained as being due to the partial cessation of production by the Canadian Copper Company, whose new smelting plant was finished and put in operation during the year, and to the suspension of the treatment of their own ores by the Mond Nickel Company. The latter's Bessemer converters were in use part of the year by the Canadian Copper

Company for concentrating the low-grade mattes made at Copper Cliff. The Creighton nickel mine continues to produce from its open-cast workings most if not all of the ore smelted at Copper Cliff, the ease with which it can be mined and its high contents of nickel having for the present put all the Company's other deposits in the background. The quantity of ore exposed and in sight at the Creighton mine is estimated as equal to 20 or 25 years' supply at the present rate of extraction, which is not far from 1,000 tons per day. From the several mines owned by this company there were raised during 1904 the following quantities of ore:

	Tons
Copper Cliff	14,713
No. 2	336
Creighton	169,911
Total	184,960

The Mond Nickel Company, whose works are situated at Victoria Mines, smelted no ore last year, but raised 5,935 tons from their Victoria No. 1 mine, and 12,493 tons from the North Star, a property recently acquired from Mr. A. McCharles of Sudbury. This company is making arrangements to re-open its mines and works.

None of the other companies or firms interested in the Sudbury nickel district engaged in active business last year, and it seems as if other concerns were chary of entering into competition with those already established in the field. Mr. Thomas A. Edison, the famous electrician and inventor, whose experts prospected the nickel belt with magnetic instruments in the hope of locating hidden or underground bodies of ore, has not, so far as known, met with great success, but it is understood there is a likelihood of his re-entering the field and resuming operations. The northern nickel range, owing to lack of railway facilities, has not yet become the scene of actual mining. Should a line be built from Sudbury or some other point on the Canadian Pacific across the northern range to the iron ore bodies in Hutton township, it would probably give life and activity to both these regions, whose resources will continue to lie dormant until that day arrives. Neither nickel nor iron mines can be opened up or worked unless served by a railway.

One feature which marks the development of industrial activity in the nickel region is the use which is beginning to be made of the water powers with which it has been by nature lavishly endowed. For instance, on the Vermilion river in Creighton township, at High falls on the Spanish near Turbine station, and in Dryden township on the Wahnapitae, three separate water power developments are in progress at the present time, each on a considerable scale, the first and last with a view to supplying the towns, villages and mines with cheaper power than can at present be obtained by the use of steam, and also no doubt in the hope of assisting to locate in the neighborhood industrial enterprises requiring considerable motive energy, such as pulp and paper mills, woodworking establishments, etc. The privilege on the Spanish river is being improved by the Canadian Copper Company for supplying power to operate its mines, provide electric lighting, etc. Now that the electrical transmission of energy generated by falling water has so immensely increased the usefulness of water powers by lengthening the radius within which they can be used, it may be expected that similar developments will take place in many other parts of northern Ontario, in which water powers, large and small, are numerous.

The quantity of nickel contained in the silver-cobalt-nickel ores of Coleman township shipped during the year was 14 tons.

The following table gives statistics of nickel and copper production for the past year, and for the sake of comparison, similar details for the four preceding years:

Nickel-Copper Mining 1900 to 1904

Schedule		1900	1901	1902	1903	1904
Ore raised	tons.	216,695	326,945	269,538	152,940	[illegible]
Ore smelted	"	211,960	270,380	233,388	220,937	[illegible]
Ordinary matte produced	"	23,336	29,588	21,691	30,416	19,123
High grade matte produced	"	112	15,546	13,332	14,419	6,926
Nickel contents	"	3,540	4,441	5,945	6,998	4,743
Copper contents	"	3,364	4,197	4,066	4,005	2,163
Value of Nickel	$	756,626	1,859,970	2,210,961	2,499,068	1,516,747
Value of Copper	"	319,681	589,080	616,763	583,646	297,126
Wages paid	"	728,946	1,045,889	835,050	746,147	570,901
Men employed	No.	1,444	2,284	1,445	1,277	1,063

The quality of the Creighton ore is reflected in the figures given above, which show that the ore smelted contained an average of 4.58 per cent. of nickel, which is 1.42 per cent. in excess of the average contents of the ore treated in 1903. In fact ever since the rich product of the Creighton mine has begun to be used by the Canadian Copper Company, the average nickel contents of the ore have appreciably risen. Thus, while in 1901 the ore contained on an average 1.64 per cent. nickel, in 1902 it carried 2.54 per cent., in 1903 3.16 per cent., and in 1904, when virtually only Creighton ore was used, 4.58 per cent.

The values given in the foregoing table are based on the selling prices of nickel and copper in the matte, in which form the metals are exported for refining in the United States and Great Britain.

The productive copper mines of Ontario are the deposits of the Sudbury region, worked for nickel as the chief object of quest, though at the first it was the chalcopyrite showings at the surface that attracted attention. The purely copper ore bodies, situated mainly on the north shore of lake Huron, of which the once famous Bruce mines is the best known example, are in the aggregate important, and will doubtless in time contribute more largely to the output than they do at present. The Massey and Hermina mines, near Massey Station on the Sault Ste. Marie branch of the Canadian Pacific Railway, the Superior mine near Sault Ste. Marie, and the Tip-top mine west of Port Arthur are all on sulphide deposits. The first mentioned has been systematically developed, and its workings are now fairly extensive. An Elmore oil concentrating plant was installed at the Massey mine last year, the first in Ontario, if not in Canada, and the results of its operation are said to be satisfactory. It is claimed for the Elmore process that it is peculiarly suited to the saving of finely disseminated copper sulphides such as characterize the Massey mine. The output of the non-nickeliferous copper mines in 1904, as returned to the Bureau of Mines, was not large, amounting to some 2,700 tons of ore containing about 121 tons of copper. These figures, as well as those of other details of production, are included in the table given above.

The copper contents of the nickel-copper ores smelted in 1904 averaged 1.86 per cent., thus evidencing the fact that the ore of the Creighton mine is much less rich in copper than in nickel.

IRON ORE

Shipments from the iron mines of the Province in 1904 amounted to 128,253 tons, but as some 75,000 tons of this were included in the returns of 1903 as having been mined in that year, the net product must be set down as 53,253 tons, compared with an output of 208,154 tons raised in 1903. As the chief working property is the Helen mine in Michipicoten, the production of iron ore fluctuates with the fortunes of the Helen. In 1903 the troubles which overwhelmed the allied companies at Sault Ste. Marie closed the mine before the end of the season of navigation, and although

it was kept dry, pending the re-organization of the business, raising ore was not resumed until 14th July of last year. The ore shipped was consigned to Cleveland and Point Edward, cargoes for the former port amounting to 77,390 tons being for M. Hanna and Company, and the Point Edward shipments for the Hamilton Steel and Iron Company, Hamilton, Ont. The prospects for a large yield from the Helen during 1905 are excellent, since it is now being worked vigorously, and is turning out ore at the rate of 1,000 tons per day. Recent examinations show that the ore body 180 feet below the old level of Boyer lake seems to be as large as ever, and the ore of as high a grade. A shaft 120 feet lower will give access to ore nearly 400 feet below the top of the original ore body.

A small quantity of hematite was got out at the Williams iron mine, in the township of Deroche, part of which was shipped to the blast furnace at Sault Ste. Marie. The quantity guaranteed by the shippers is a minimum of 50 per cent. iron (in natural condition of ore), and a maximum contents of 0.03 per cent. phosphorus, and 0.05 per cent. sulphur. About 6 to 10 per cent. of this ore can be used in the blast furnace for Bessemer pig.

The only other productive mine last year was the Radnor, near Eganville, the property of the Canada Iron Furnace Company. This yields a magnetic ore which is used by the company to mix with the bog ores smelted in their Quebec furnaces.

The quest for iron ores still continues. At Loon lake, east of Port Arthur, diamond drill borings and other tests have been carried on and there seems now to be little doubt that the hematite deposits of this region will prove of very considerable value, notwithstanding the fact that a proportion of the ore is not high in metallic iron. On the banded outcroppings of magnetite on the northeast arm of lake Temagami a diamond drill was expected to obtain evidence regarding the character of the deposit in depth, but unforeseen difficulties were encountered during the progress of the work which have caused it to be suspended. First, a very strong flow of artesian water was struck, and when after much labor this was got under control, the drill entered a seam of extremely hard gravel or fragments of rock, in which the bit revolved without making any headway. It is to be hoped further development work will be undertaken at an early date, so as to demonstrate whether the range contains bodies of concentrated ore, or whether the surface conditions persist at depth. In the latter case the aggregate quantity of ore will still be very large, but it will contain so high a proportion of silica as to render artificial concentration necessary. Some of the processes of magnetic concentration in vogue in the United States or elsewhere could no doubt be applied with success.

There are indications of a new hematite field on the western shore of lake Temiskaming, between the villages of Haileybury and New Liskeard, where outcroppings occur not far from the water's edge. Some miles to the west fragments of iron formation may be seen, and altogether the conditions are such as to afford color to the conjecture that a buried range may exist overlaid not only by the Niagara limestones, but also by a heavy burden of clay. A diamond drill would be the best implement for setting the question at rest.

The Hutton range has remained untouched throughout the year, and will probably continue quiescent until the advent of a railway enables machinery to be taken in to open it up and provide the means for transporting the ore to market.

The deposits of magnetic ore on the Atik-okan river and near the Canadian Northern railway station of the same name are likely to form the scene of active operations if the intentions of the parties composing the Atikokan Iron Company, of which a brief statement is given below, are carried into effect.

The account of the explorations carried on last year for the Bureau of Mines by Dr. James M. Bell, in the iron ranges of Michipicoten will be read with interest, as showing that there is much ground in that district yet to be carefully looked over before it can be assumed that all the workable deposits have been located.

A brief paper on the Boston iron range, situated in the township of that name, which lies in the Temiskaming district near the height of land, gives the results of an examination of the tract made by the Provincial Geologist last year.

PIG IRON and STEEL

There was produced in the blast furnaces of Ontario last year a total of 127,845 tons of pig iron, valued at $1,811,664, a considerable increase over the output of 1903, which was 87,004 tons, worth $1,491,696. Of charcoal iron the quantity made was 10,462 tons, having a value of $140,112, the remainder, 117,383 tons, being coke iron worth $1,671,552. The average value of the charcoal iron produced was returned as $13.39 per ton and of coke iron as $14.24 per ton, (2,000 lb.), which is a decided reduction from the prices of 1903, namely $15.46 and $17.40 per ton respectively.

The ore smelted to produce the above quantity of pig iron was 223,605 tons, of which 50,423 tons were raised from mines in Ontario, and 173,182 tons imported from the United States.

The number of blast furnaces in operation during 1904 was four, as compared with three in 1903, the increase being due to the blowing in of one of the coke furnaces of the Algoma Steel Company, Limited, at Sault Ste. Marie.

A project has been launched for the erection of a blast furnace at Port Arthur by the Atik-okan Iron Company, with the view of utilizing the magnetic ores of the Atik-okan range, and also of exporting the surplus mined from these deposits to furnaces in the United States and Canada. The nominal capital of the Company is $1,000,000, and the money for purchasing the mines and erecting the furnace is to be provided by issuing bonds to the extent of $1,000,000, of which Messrs. Mackenzie, Mann and Company are to take $400,000 worth, the town of Port Arthur, by way of assisting the enterprise, $300,000 worth, and a group of American capitalists composed of Messrs. J. C. Hunter, Duluth,and De C. O'Grady and Stamford White of Chicago, the remainder. Messrs. Mackenzie, Mann and Company have taken an active part in promoting the company, their object being to bring about the development of the iron ore resources of the territory in question, as well as to provide traffic for the Canadian Northern railway. The furnace is to have a capacity of 100 tons of pig iron per day, there is to be an ore-roasting plant capable of treating 300 tons of pig per day, and ovens for making coke. The officers of the company are D. D. Mann, president, J. C. Hunter, vice-president, R. M. Hunter, secretary, H. Sutherland, treasurer. The head office is at Toronto. The municipalities of Port Arthur and Fort William have agreed to provide a free site for the erection of the plant, with exemption from taxation.

Connected with the enterprise is the Canadian Coal and Ore Dock Company in which Messrs. Mackenzie, Mann and Company are interested, and in which they have associated with them certain coal operators of Pittsburg, Pennsylvania. Docks for loading ore and unloading coal are to be constructed, and it is expected that the facilities provided will do much to promote the welfare both of the iron and coal industries of this part of the Province.

There can be no doubt that a very large market for pig iron and for manufactures of iron and steel in every possible form is opening up on the prairies of the Northwest and in the bush lands of northern Ontario. For the making of iron and steel destined to supply these markets, it is surely more economical to bring the coal from lake Erie ports to lake Superior than to ship the ore from lake Superior to the shores of lake Erie, convert it into pig iron or manufactured goods and then pay freight on these back again over the same route previously traversed by the ore. It is reasonable to suppose that the line of least resistance will be found to exist in this direction, and that notwithstanding the long established customs and course of trade, there is a future ahead for an iron making and iron working industry established at the head of navigation on the western shores of lake Superior.

The steel made by the Hamilton Steel and Iron Company and The Algoma Steel Company together amounted to 51,002 tons, valued at $1,188,349. Open-hearth steel for various uses is produced by the former, while the output of the latter consisted wholly of steel rails.

The statistics of the pig iron and steel manufacture for 1904 are as follows:

Ontario ore smelted	tons	50,423
Foreign " "	"	173,182
Scale and Mill cinder	"	12,776
Limestone for flux	"	61,566
Coke for fuel	"	135,108
Value of fuel	$	577,138
Charcoal for fuel	bush	1,821,270
Value of fuel	$	72,851
Pig iron product	tons	127,845
Value of product	$	1,811,664
Steel product	tons	51,002
Value of product	$	1,188,349
Workmen employed	No.	1,522
Wages paid	$	539,482

The following table gives details of the iron and steel making industry of the Province for the last five years:

Production Iron and Steel 1900 to 1904

Schedule.		1900.	1901.	1902.	1903.	1904.
Ontario ore smelted	tons.	22,887	109,109	92,883	48,092	50,423
Foreign ore smelted	"	77,805	85,401	94,079	103,137	173,182
Limestone flux	"	24,927	51,452	58,885	49,426	61,566
Coke	"	59,345	113,119	111,390	96,540	135,108
Charcoal	bush.	955,437	915,789	968,623	932,630	1,821,270
Pig iron	tons.	62,386	116,370	112,687	87,004	127,845
Value pig iron	$	936,066	1.701,703	1,683,051	1,491,696	1,811,664
Steel	tons.	2,819	14,471	68,802	15,229	51,002
Value	$	46,380	347,280	1,610,031	304,580	1,188,349

The Iron Mining Fund, consisting of a sum of $125,000 originally set aside by the Legislature in 1894, to encourage the production of iron ore and pig iron in Ontario, out of which $109,741.01 had been earned up to 31 October, 1903, was exhausted by payment of the bounties earned during the year ending 31 October, 1904. The provisions of the law were such that no more than $25,000 could be paid out in any one year at the maximum rate of $1 per ton of pig iron produced, and that if more ore were raised and smelted than could be paid for out of $25,000 at $1 per ton of pig metal, the rate of bounty should suffer a proportionate reduction. The quantity of pig iron smelted from Ontario ore eligible for bounty during the 12 months ending with October, 1904, being 50,715 tons, 331 lb., and the amount available for payment of bounty thereon being $15,236.19, the rate per ton of pig iron was $0.551. The following figures give details of the payments.

Name.	Tons Ontario ore smelted.	Tons pig iron produced.	Bounty.
			$ c.
Canada Iron Furnace Co, Ltd., Midland	11,676	5,877	3,238 75
Hamilton Steel and Iron Co. Hamilton	39,039	21,771	11,997 44
Total	50,715	27,648	15,236 19

No provision having been made by the Legislature for the renewal or extension of this system of assistance to the iron ore and pig iron industry, the Iron Mining Fund has become a thing of the past.

The following table shows how the total sum of $125,000 has been expended.

Bounty on Iron Ore 1896 to 1904.

Year.	Pig iron product Ontario ore. Tons.	Bounty paid. $
1896	4,000 00	4,000 00
1897	2,603 95	2,603 95
1898	8,647 19	8,647 19
1899	12,752 07	12,752 07
1900	6,737 80	6,737 80
1901	55,214 00	25,000 00
1902	53,868 22	25,000 00
1903	26,699 28	25,000 00
1904	50,715 17	15,236 19
Sundry expenses	....	22 80
Total	221,237 68	125,000 00

LEAD

The Ontario Mining and Smelting Company are continuing to develop the Hollandia lead mine, near Banockburn, in the county of Hastings, and last year reported an output of 3,210 tons of ore, of which a sufficient quantity was smelted in the company's own plant to produce 43 tons of pig lead, valued at $2,500.

ZINC

The Olden zinc mine near Long lake in the county of Frontenac, was under development last year, and some 533 tons of ore worth $3,700 were extracted. A deposit of some promise is under development near Wolf River, east of Port Arthur.

BUILDING MATERIALS

Under this heading may be grouped stone, lime and brick. Cement is also an important construction material, but it will be more convenient to deal with it in a separate paragraph.

Stone

The quarries of Ontario produced during 1904 a quantity of stone used largely for building purposes but also for road making, concrete work, etc. Much the larger part was derived from the limestone formations of varying age and composition, so plentifully developed in southern Ontario; to a smaller extent the sandstones, such as those of the Medina and Potsdam formations, and the granite, gneiss and trap of Archean age, were also drawn upon. A full account of the limestones of the Province by Prof. W. G. Miller, Provincial Geologist, will be found in Part II of the Bureau's Thirteenth Report, where their distribution, uses, composition, etc., are dealt with. Similar work remains to be done in connection with the sandstones of the Province, but especially with the granites, gneisses and traps of northern and eastern Ontario which occur in inexhaustible quantity and great variety.

It is passing strange that in a country so well provided with granite as Ontario, conveniently situated, too, as much of it is for shipment by water, practically none of the native material is made use of by our stone-cutters or monument-makers. Very much of the polished granite seen in our cemeteries and adorning the fronts of business blocks is turned out of the stone yards of Aberdeen, Scotland, but is really brought in the rough to that place by sea from Sweden and Norway. What Scandinavia does not furnish us, via Scotland, is sent by Massachusetts, Vermont and Quebec, but one will look almost in vain for shaft or pillar for which a domestic origin can be claimed. Surface fissures and seams have discouraged some of the attempts made to

open up granite quarries in the north, and trade customs and fashions once established are hard to change, but it seems reasonable to suppose that among the hundreds, if not thousands, of conveniently situated beds of granite and gneiss in Ontario, hand specimens of which when polished present a wealth and play of color not inferior to the imported article, suitable sites might be selected which capital and skill could convert into remunerative and abundant sources of first-class material.

The tendency, noted in the last Report, to the extinction of small quarries and the absorption of the trade by large and well-appointed works, continues unabated. Apparently, for anything except local and transient use, the day of the small quarry is nearly over.

Lime

The same prevalence of limestone which provides a plentiful supply of building stone in so many parts of the Province, guarantees an equally abundant supply of lime—an article whose usefulness is by no means confined to building purposes. There was a fairly active demand for lime last year, notwithstanding that the returns made to the Bureau indicate a somewhat lessened production as compared with 1905. The average price per bushel advanced slightly over that of the previous year, being 15.6 cents, as compared with 15.3 cents. In lime-making, as in stone-quarrying, the small producer is fast dropping out of competition with his better-equipped rivals who produce on a large scale and are possessed of modern and economical plants.

Brick

The returns of brick made in Ontario point to a smaller production in 1904 than in 1903. The unusually active demand not only in Toronto, where building was very brisk and a large burned-over area had to be rebuilt, but in practically all the cities and towns of the Province, led to a material advance in price, the average cost of bricks at the yard, which in 1902 was $6.41, and in 1903 $6.78 per thousand, having risen in 1904 to $7.15 per thousand.

Slightly larger quantities of pressed brick and paving brick were made last year in comparison with 1903. For better-class houses in the cities, fronts, etc., pressed (or rather re-pressed) brick is in good demand at considerably higher prices than are paid for common brick. The use of vitrified brick for street pavements has not extended so rapidly as was anticipated some years ago. The principal objections are two, (1) the noisiness of the pavement, and (2) the difficulty of obtaining brick possessing the necessary wear-resisting qualities.

Other manufactures of clay are sewer pipe, drain tile and pottery. Of the former $283,000 worth was made last year—a considerable advance over 1903, when the output was valued at $199,971—and pottery, which aggregated about $100,000 in value, as compared with $160,000 in the previous year.

Sewer pipe is made at Toronto and Hamilton, and another company is being organized to utilize the shales of the Medina formation, outcropping on the Credit river, in the manufacture of the same article. Notwithstanding the increase in the home product, sewer pipe continues to be brought into the country in considerable quantity.

Drain tile is made to the value of about $200,000 annually, the output for 1904 being $210,000. It is produced principally in the southern and southwestern portions of the Province, in localities where farming is most advanced, and especially where the low-lying nature of the land requires ample facilities for speedily ridding the soil of superfluous precipitation. For the most part drain tile is made in brick factories, but occasionally a business is carried on for the manufacture of tile only.

The class of pottery made from the domestic clays of this Province is of the commonest kind, such as flower pots, jardinieres, etc. Better goods are manufactured to some extent, but for such purposes the clay is imported, mainly from New Jersey.

If clays or shales of the requisite quality can be found in Ontario, large industries could be built up in the manufacture of china and tableware, as well as fire-brick and other refractory goods. To be adapted for such uses, clay must be characterized by an absence, or at any rate a minimum of fluxing ingredients, such as lime, potash, soda, iron, etc. The prevalence of limestone and lime-bearing rocks in this Province, and the absence of the Carboniferous series with its accompanying seams of fire-clay do not provide the best conditions for the occurrence of clay or shale beds of the right kind, while the severe scouring to which the rock formations have been subjected in glacial times explains the lack of residual clay deposits found in countries where ice action has been less energetic. It is known, however, that clay beds of refractory or semi-refractory character, and also of kaolin, apparently suitable for making china and porcelain, are found on the Abitibi and other rivers of the northern slope, more or less associated with deposits of lignite. The construction of the Grand Trunk Pacific and extension of the Temiskaming and Northern Ontario railways will make these regions more accessible, but careful search nearer civilization is warranted in the hope that local deposits may be found capable of supplying the raw materials for what would in all probability become a thriving industry .

The important place which clay and shale occupy in the industrial arts is perhaps not generally or fully recognized. A bed of shale or a bank of clay makes no such appeal to the imagination as does a gold or silver mine, and indeed there are not a few people by whom the title "mineral" as applied to either clay or shale would not at first be admitted. Yet in Ontario, as in many other countries, the goods manufactured from clay surpass in value many times the combined output of gold and silver. For example, the united value of the articles made of clay in this Province last year, including bricks of all kinds, tile drain, pottery and sewer pipe, was $2,305,200, while of gold and silver the yield was only worth $151,887. If a proportion of the cement product, in which clay is also an important ingredient, were included. the balance in favor clay manufactures would be still greater. Undoubtedly the chief element of value in such goods is the labor expended in producing them, but they cannot be made unless the raw materials of the proper quality exist.

In view of the great importance of the various industries which employ clay as their raw material, the Bureau of Mines has set about making an investigation of the clay and shale resources of the Province in the hope of collecting data that will be of service to those engaged in these industries, and may perhaps lead to an enlargement of the uses to which the wealth of clay and shale in Ontario may profitably be applied. This work will be under the supervision of Prof. Miller, the Provincial Geologist, who will be assisted by Mr. M. B. Baker, and it is hoped to complete it during the field season of 1905.

CEMENT

The cement made in Ontario is of two kinds, (1) Natural rock, and (2) Portland.

The manufacture of natural rock cement is not increasing, this article being less highly regarded than Portland cement, notwithstanding that for many purposes it is an efficient and satisfactory substitute. The production in 1904 as reported to the Bureau was 85,000 barrels worth $65,250, comparing with 89,549 barrels in 1903 worth $69,319. The average selling price at the factories remained the same as last year, namely 77 cents per barrel.

In the Portland cement industry the expansion commented on in previous reports continued during 1904, the production rising in quantity from 695,260 barrels in 1903 to 880,871 barrels in 1904, and in value from $1,182,799 to $1,239,971, the rate of increase as measured by output being 26 per cent. The price however, fell off considerably, averaging at the works $1.40 per barrel as against $1.70 in 1903. The number

of producing companies last year was nine, the Ontario Portland Cement Company's plant at Blue lake, near Brantford, having begun production during the year. Other factories in various stages of completion when the year closed were those of the Belleville Portland Cement Company, Belleville, the Western Ontario Portland Cement Company, Atwood, and the Colonial Cement Company, Wiarton. The Raven Lake Cement Company, Raven lake, went into operation just at the end of 1904. It is unnecessary to make further comment on the Portland cement industry of Ontario here, since in the present volume a detailed report upon it by Mr. P. Gillespie will be found.

The progress of both branches of cement-making in Ontario since 1891 is set out in the subjoined table.

Production of Cement 1891 to 1904

Year.	Natural rock.		Portland.		Total.	
	bbl.	value. $	bbl.	value. $	bbl.	value. $
1891	46,178	39,419	2,033	5,082	48,211	44,501
1892	54,155	38,580	20,247	47,417	74,402	85,997
1893	74,353	63,567	31,924	63,848	106,277	127,415
1894	55,323	48,774	30,580	61,060	85,903	109,834
1895	55,219	45,145	58,699	114,332	113,918	159,477
1896	60,705	44,100	77,760	138,230	138,465	182,330
1897	84,670	76,123	96,825	170,302	181,495	246,425
1898	91,528	74,222	153,348	302,096	244,876	376,318
1899	139,487	117,039	222,550	444,227	362,037	561,266
1900	125,428	99,994	306,726	598,021	432,154	698,015
1901	138,628	107,625	350,660	563,255	489,288	670,880
1902	77,300	50,795	522,899	916,221	609,199	967,016
1903	89,549	69,319	695,260	1,182,799	784,809	1,222,118
1904	85,000	65,250	880,871	1,239,971	965,871	1,305,221

The number of persons employed in making natural rock cement was 60, and the amount paid out in wages $22,050; and in Portland cement 734 and $323,689 respectively.

CALCIUM CARBIDE

There are two plants engaged in the manufacture of calcium carbide, the Ottawa Carbide Company at Ottawa, and the Willson Carbide Company at Merritton. Their combined output for 1904 was 2,343 tons valued at $152,295, as compared with 2,507 tons worth $144,000 in 1903. The slight falling off in production was thus accompanied by a rise in the price per ton from $57.43 to $65.

The following table gives details of the industry for the last five years:

Calcium Carbide 1900 to 1904

Schedule.	1900.	1901.	1902.	1903.	1904.
Carbide produced .... tons	1,005	2,771	1,402	2,507	2,343
Value of product .... $	60,300	168,792	89,420	144,000	152,295
Workmen employed .... No.	32	83	57	66	78
Wages paid .... $	72,584	40,788	28,965	33,934	35,200

CORUNDUM

The quantity of grain corundum produced from the deposits of Raglan and Carlow townships, in the counties of Renfrew and Hastings respectively, during 1904, was 1,665 tons valued at $150,645, compared with 1,119 tons worth $87,600 in 1903. The

producing companies continue two in number, namely, the Canada Corundum Company, and the Ashland Emery and Corundum Company, formerly the Ontario Corundum Company. The mines and works of the former are situated at Craigmont in the township of Raglan, and of the latter at New Carlow in the township of Carlow, which adjoins Raglan. Corundum Refiners, Limited, mentioned in the report for last year, have not yet begun production.

Statistics of the corundum business since 1900, when the first production was made, are as under:

Corundum 1900 to 1904

Schedule.	1900.	1901.	1902.	1903.	1904.
Corundum produced ....tons	60	584	1,137	1,119	1,665
Value of product........................... $	6,000	53,115	88,871	87,600	150,645
Workmen ....No.	35	68	95	186	202
Wages paid .... $	10,000	30,406	34,674	106,332	139,548

FELDSPAR

The feldspar or microcline quarries on the line of the Kingston and Pembroke railway last year had an output of 10,983 tons valued at $21,966, which was 4,313 tons less in quantity and $1,920 more in value than the production of 1903. In the latter year the product was given an average value at the mine of $1.31, and in 1904 of $2 per ton. The market is wholly in the United States, mainly among the potteries of New Jersey and Ohio.

For the last five years the figures for the feldspar industry are as follows:

	Tons.	Value.
1900....	4,000	$ 5,000
1901......	5,100	6,375
1902...	8,776	12,875
1903........	15,296	20,046
1904......	10,983	21,966

The number of employees in 1904 was 34, and the amount paid in wages $16,300. The Kingston Feldspar Mining Company and Mr. Charles Jenkins were the producers.

IRON PYRITES

The production of iron pyrites has increased with some rapidity during the last two or three years, the output in 1904 being 13,451 tons worth $43,716, as against 7,469 tons valued at $21,693 in 1903. The chief producer is the American Madoc Mining Company, which operates two deposits in the county of Hastings, one near Bannockburn, and the other in the township of Hungerford. Another mine in the same county is being opened by the British America Mining Company of Toronto. The product is shipped to the United States, where it is used in the manufacture of sulphuric acid.

For the four years beginning with 1901, the production of iron pyrites in Ontario has been as follows:

	Tons.	Value.
1901......	7,000	$17,500
1902...	4,371	14,993
1903......	7,469	21,693
1904......	13,451	43,716

In mining iron pyrites 60 persons were employed in 1904 to whom $22,875 was paid in wages.

MICA

There was a lull in the mica business last year, some 332 tons only of the amber variety having been raised from the mines of this Province, valued at $37,847, as compared with 948 tons worth $102,205 in 1903. The chief producers were the General Electric Company, Sydenham, and Jas. Richardson and Sons and Kent Bros., both ot Kingston. The number of persons employed in mining mica last year was 79, and the amount of wages paid them $21,529.

SALT

The brine wells of southwestern Ontario in 1904 produced a total of 55,877 tons of salt, valued at $362,621, as against 58,274 tons worth $388,097 in 1903. The market for Ontario salt does not seem to be increasing, since the output is now less than it was five years ago. The largest producer is the Canadian Salt Company of Windsor, but there are also working plants at Goderich, Wingham, Seaforth, Clinton and Brussels in the county of Huron, Kincardine in the county of Bruce, and Sarnia in the county of Lambton.

The course of the salt business in Ontario for the last five years is shown by the following figures:

Production of Salt 1900 to 1904.

Schedule.	1900.	1901.	1902.	1903.	1904.
Salt produced ....tons	66,588	60,327	62,011	58,274	55,877
Value of product........................ $	324,477	323,058	344,620	388,097	362,621
Workmen employed....................No	243	189	198	208	193
Wages paid.............................. $	72,581	67,024	76,154	87,995	84,682

PETROLEUM

The decline in the yield of the petroleum wells of the Province, which has been going on almost uninterruptedly for a number of years, appears to have suffered a check in 1904. The crude product last year was 17,237,220 imperial gallons, as against 16,640,338 imperial gallons in 1903. The value did not rise in proportion, being $904,437, compared with $12,103,016. The increased production is to be credited to the new pools or fields near Leamington, Essex county, which began production in 1903, and in the township of Moore, Lambton county, opened up last year, which yielded 25,241 barrels and 36,971 barrels respectively, the output of these new areas being more than sufficient to offset the shrinkage in the Petrolea district. The production of the various fields, or pools, is estimated as follows, a barrel being the equivalent of 35 imperial gallons:

Field.	Barrels.
Petrolea....	278,299
Oil Springs........	75,530
Bothwell....	47,654
Dutton	14,217
Leamington....	25,241
Moore....	36,971
Wheatley......	4,490
Raleigh......	3,274
Thamesville........	5,027
Pelee Island......	1,023
Blytheswood....	669
Comber......	97
Total....	492,492

On 8th June 1904 the bounty on Canadian crude petroleum of one and one-half cent per imperial gallon provided by the Dominion Government under chap. 28, 4

Edward VII, became effective—applying as well to oil held in storage tanks or other storage receptacles as to oil produced after that date—and the effect of this encouragement was no doubt to stimulate the production of domestic crude. The quantity of crude petroleum in storage on 8th June and delivered to 31st December, was 9,817,447 gallons, on which a bounty was paid of $147,261.70.

As stated above, the prices of crude oil in Canada as well as in the United States, declined during the year. On June 7th, just before the bounty took effect, and while the import duty of five cents per gallon was in force, the price of Oil Springs, Bothwell and Dutton crude was $2.13 per barrel, and of North Lima crude $1.11 per barrel; on 31st December, the price for Canadian crude was $1.50 per barrel plus bounty 52½ cents per barrel, total $2.02½ per barrel, while the North Lima article sold for $1.01 per barrel.

It is estimated that about 30,555 barrels of domestic crude petroleum were used for fuel and gas-making purposes, leaving say 461,937 barrels available for distillation. This was implemented by the treatment of a large quantity of crude imported from the United States in order to supply the demand for petroleum products and keep the refineries in operation. Since the beginning of 1905 developments, especially in the Leamington field, seem to indicate that a very considerable addition to the supplies of Ontario crude may be looked for, and some are sanguine enough to hope that the output of the Canadian wells may soon prove sufficient to meet the requirements of the home market. The account given in this Report by Mr. E. T. Corkill, Inspector of Mines, who visited the oil and gas fields in the early spring of the present year, will be read with interest.

Owing to the large quantities of American oil now treated in the refineries of the Province along with the domestic article, it is no longer practicable to give the refined products derived from the latter in separate form, hence in the table of statistics the figures are presented of the crude product only.

NATURAL GAS

There was a marked increase in the quantity of natural gas produced in the Province last year as compared with 1903, the value of the output in 1904 being $253,524, and that of the previous year $196,535. The greater portion of the gas is derived from the Welland county field, in which the Provincial Natural Gas and Fuel Company is the principal operator, but in the county of Haldimand a gas field of apparent promise is being exploited with some success. It is proposed to pipe the gas from this district into the city of Hamilton. On the outskirts of Brantford both gas and oil have been found at Bow Park farm and elsewhere, and gas is being supplied for illuminating purposes to the people of that city. In the new oil field at Leamington much gas accompanies the oil, and the inhabitants of that town are once more enjoying the advantages of a gas supply, of which they were deprived when the Essex wells ceased to flow two or three years ago.

A feature of the Provincial Natural Gas and Fuel Company's operations last year was the extension of their supply line to the city of Niagara Falls, Ont., and to the neighboring village of Chippewa. Thirty miles of low pressure lines composed of 6-inch, 4-inch, 3-inch and 2-inch pipes were laid in Niagara Falls and three miles of 3-inch and 2-inch at Chippewa. About 3 miles of 1½-inch and 1¼-inch pipe were put in as service lines from the mains to the meters, and in all some 1,600 new customers were connected during the year. The price at which the gas is sold at these points is 20 cents per thousand cubic feet. Gas is also delivered by that company at Bridgeburg, Fort Erie, Sherkston, Stevensville, Crystal Beach, and other points along the lake shore, as well as to farmers situated along the lines. At these places the price of the gas is 25 cents per thousand cubic feet.

The production of natural gas in the Province for the last five years has been as follows:

Year.	Value.
1900	$392,823
1901	342,183
1902	199,238
1903	196,535
1904	253,524

At the close of 1904 there were 176 producing wells, of which 36 had been put down during the year; there were also 231 miles of delivery pipe, and the number of employees was 98, to whom $53,674 was paid in wages. There were also drilled during the year 13 non-producing wells.

MINOR PRODUCTS

Of actinolite a small quantity—408 tons—was exported during the year, from a deposit in Frontenac county, being valued in the returns at $102. A mill for grinding actinolite into raw material for making fire-proof roofing, paint, etc., has been for many years in existence at Actinolite (formerly Bridgewater) but was last year injured by a flood on the Moira river to such an extent as to cause its stoppage.

The production of arsenic in Ontario suffered an interruption when the Deloro mines were closed down about two years ago, the auriferous mispickel in which furnished a very appreciable proportion of the white arsenic consumed on the continent. A new source of this product has been opened up in the cobalt and nickel arsenides of Coleman township, which have already been mentioned under several headings. The output of last year was wholly from this source, and amounted to 72 tons of arsenic contained in the exported ore, valued at $903. Efforts have been made to bring about a resumption of operations at Deloro, where and in which vicinity there are undoubtedly large bodies of arsenical ore, and some enquiry has also been made into the possibility of establishing works in Coleman to recover this substance from the ores produced there, a nominal price only being realized at present for their arsenical contents.

The graphite obtained last year amounted to 235 tons of the crude article, valued at $4,700. Part of this was refined at the point of production, and part was used in the natural condition. The mines and works at Oliver's Ferry were idle during the year, but an amalgamation of interests has been effected which is likely to lead to renewed activity at that place. The Black Donald mine in Brougham township, formerly operated by the Ontario Graphite Company of Ottawa, has been leased to Mr. Rinaldo McConnell, who took possession 1st May 1904. Being largely interested in the Globe Refining works at Oliver's Ferry, which is now in control of the graphite properties at that place, Mr. McConnell is probably more extensively engaged in the graphite business than any other person in the Province.

From the palaeozoic rocks of the Onondaga formation outcroppings in the valley of the Grand river small quantities of gypsum continue to be mined or quarried from year to year. Formerly this article was more or less in vogue as a fertilizer on certain kinds of soil, but it is now for the most part utilized in the manufacture of wall plaster, kalsomining materials, etc., for which there are factories at Paris and Toronto. There was raised in 1904, 5,412 tons of crude gypsum, worth $10,674. The immense deposits on the banks of the Moose river, described in some detail by Dr. James M. Bell in the Thirteenth Report of the Bureau of Mines will no doubt remain unworked until better means of communication and transport are provided.

In the peat bogs of Ontario is stored up a prodigious quantity of carbon, which may yet be drawn upon in a commercial way and used as fuel. The manufacture of compressed peat by the Dobson process continues at Beaverton, where some 800 tons, worth $2,400, were made in 1904. This industry is also being established at Alfred,

where a plant capable of turning out 50 tons of fuel per day has been erected by the Montreal & Ottawa Peat Co., Limited, with a capital of $75,000 and head office at Ottawa, of which George H. Perley is president and A. W. Fleck secretary-treasurer. The company own a peat-bog comprising 300 acres of first-class quality adjoining the railway. Lying about midway between Ottawa and Montreal, this factory will send fuel into both markets. At the other end of the Province, near Fort Frances, a factory is being put up by the Manitoba Peat Company to work a very large bog of good quality. If a good article of fuel can be produced, of which the promoters of the company have no doubt, it is sure of a free sale in Winnipeg, where anthracite sells for $11 per ton and more, and where in consequence the fuel question is a pressing one. An effort is being made by Messrs, D. H. and E. V. Moore of Peterborough, to introduce the manufacture of peat fuel by the "machine" methods so commonly used in Europe. It is claimed for "machine" peat that being compacted by shrinkage during the process of drying, it will not disintegrate when burning, an objection brought against the briquettes made by compression. Mr. Moore has installed an experimental plant at Victoria Road.

The county of Hastings—whose mineral products excel in number and variety those of any other county in the Province—produced 1,313 tons of talc in 1904, valued at $2,919.

MINING LANDS SOLD AND LEASED

The sales of land for mining purposes in 1904 covered 3,440 acres, and the purchase money received was $8,321.80, as against 6,437 acres sold for $15,123.89 the previous year. The average price per acre realized in 1904 was $2.32, and in 1903, $2.35. Prices of mining lands are regulated by the Mines Act, which provides that if in unsurveyed territory, and more than 12 miles from a railway, the rate shall be $2 per acre, if within 12 miles, but more than 6 miles of a railway, $2.50 per acre, and if nearer than 6 miles, $3 per acre. In surveyed townships, the price is 50 cents per acre more in each class.

Mining leases were issued for 11,002 acres, the first year's rental being $10,762.06, as compared with 33,427 acres and $33,177.61 in 1903.

The amount received as rental under mining leases issued prior to 1904 was $14,558.63, and on account of leases converted into freeholds, $9,920.38.

The receipts from miner's and prospector's licenses was $1,597.15.

Sales

District.	Number of Grants	Acres	Amount $
Rainy River....	13	2,184	4,923.50
Thunder Bay......		132	293.00
Algoma....	1	84	254.00
Elsewhere....	16	1,040	2,851.30
Total....	33	3,440	8,321.80

Leases

District	Number of Leases	Acres	Amount $
Rainy River....	17	2,932	2,932.00
Thunder Bay....	8	770	770.00
Algoma....	30	5,347	5,232.06
Elsewhere....	20	1,953	1,828.00
Total....	75	11,002	10,762.06

MINING COMPANIES

The following list gives particulars of the joint stock companies incorporated or licensed to carry on business in Ontario in some or all of the branches of the mineral industry. The number of companies organized under the laws of the Province was 54, with an aggregate nominal capital of $28,355,000, as against 43 companies in 1903 having a total share issue of $35,534,000. In addition 12 companies of extra-Provincial origin took out licenses enabling them to do business here, their joint combined capital amounting to $21,155,000 as against 12 such companies in 1903, having an aggregate capital of $12,000,000.

Mining Companies Incorporated 1904.

Name of Company.	Date.	Head Office.	Capital.
			$
Bonanza Creek Gold Mining Company, Limited	December 23, 1904	Toronto	1,000,000
Buffalo and Leamington Oil and Gas Company, Limited	December 9, 1904	Windsor	100,000
Canadian Lead Company, Limited	September 27, 1904	Toronto	1,000,000
Cement, Stone and Building Company, Limited	February 8, 1904	Toronto	50,000
Condensed Peat Fuel Company, Limited	December 9, 1904	Peterboro'	40,000
Dominion Cement-Brick Company, Limited	June 30, 1904	Toronto	50,000
Dorion Lead and Zinc Company, Limited	December 5, 1904	Port Arthur	50,000
Fruitland Brick and Supply Company, Limited	July 6, 1904	Hamilton	40,000
Grand Valley Peat Products, Limited	July 26, 1904	Toronto	00,000
International Peat Company, Limited	December 9, 1903	Toronto	[illegible]50,000
Mayo Mining and Development Company, Limited	January 8, 1904	Windsor	[illegible]50,000
Mohawk Natural Gas, Limited	September 7, 1904	Brantford	[illegible]50,000
New York-Lake Erie Oil and Gas Company, Limited	June 22, 1903	Windsor	1,[illegible]00,000
Orion Mining Company, Limited	January 18, 1904	Niagara Falls	1,[illegible]00,000
St. Marys Quarries, Limited	December 30, 1904	St. Marys	[illegible]00,000
Sarnia Bay Lumber, Timber and Salt Company, Limited	January 6, 1904	Sarnia	[illegible]00,000
Silver King Gold and Copper Company, Limited	June 30, 1904	Toronto	2,[illegible]00,000
Sovereign Oil Company, Limited	June 8, 1904	Comber	[illegible]50,000
Sudbury Brick Company, Limited	May 18, 1904	Sudbury	20,000
Victoria Cement and Power Company, Limited	December 20, 1903	Lindsay	00,000
Windsor Gas Company, Limited	October 24, 1904	Windsor	00,000
The Aberdeen Development Company, Limited	January 12, 1904	Tp. of Aberdeen	300,000
The Alpena Oil and Gas Company, Limited	July 27, 1904	Chatham	100,000
The Ballarat Mining Company, Limited	October 5, 1904	Toronto	300,000
The Brick Manufacturing and Supply Company, Limited	December 3, 1904	London	40 000
The British American Development Company, Limited	April 20, 1904	Toronto	1,000,000
The Canadian Cement Brick Company, Limited	January 15, 1904	Toronto	150,000
The Canadian Corundum Wheel Company, Limited	December 23, 1904	Hamilton	40,000
The Canadian Iron Company, Limited	June 15, 1904	Ottawa	2,000,000
The Canadian Michigan Gold Mines, Limited	June 15, 1904	Sault Ste. Marie	1,000,000
The Deep Oil and Gas Company, Limited	January 29, 1904	London	100,000
The Dominion Natural Gas Company, Limited	October 12, 1904	Hamilton	500,000
The East Toronto Brick Company, Limited	October 26, 1904	Toronto	40,000
The Empire Salt Company, Limited	June 22, 1904	Sarnia	50,000
The Goderich Cement Brick Company, Limited	July 29, 1904	Goderich	40,000
The Hamilton and Toronto Sewer Pipe Company, Limited	March 25, 1904	Hamilton	250,000
The Island Granite Company, Limited	March 23, 1904	Toronto	200,000
The Lake Shore Natural Gas Company, Limited	September 16, 1904	Fort Erie	500,000
The Montreal and Boston Consolidated Mining and Smelting Company, Limited	April 27, 1904	Toronto	7,500,000
The Montreal and Ottawa Peat Company, Limited	May 18, 1904	Ottawa	75,000
The Mount McKay Brick and Tile Company, Limited	September 7, 1904	Fort William	40,000
The Niagara Quarry Company, Limited	September 14, 1904	Orillia	40,000
The Nipissing Mining Company, Limited	December 16, 1904	Toronto	250,000
The Northern Iron and Steel Company, Limited	September 13, 1904	Toronto	2,500,000
The Ontario Crude Oil Company, Limited	June 30, 1904	Toronto	300,000
The Owen Sound Natural Gas and Oil Company, Limited	May 27, 1904	Owen Sound	40,000
The Point Pelee Oil and Gas Exploration Company, Limited	August 17, 1904	Leamington	40,000
The Reading Mining Company, Limited	November 30, 1904	Toronto	250,000
The St. Anthony Gold Mining Company, Limited	May 29, 1904	Ignace	1,000,000
The South Essex Oil and Gas Company, Limited	May 11, 1904	Leamington	500,000
The Syndicate Mining Company, Limited	April 15, 1904	Toronto	50,000
The Toronto Pottery Company, Limited	August 19, 1904	Toronto	10,000
The Trout Creek Development and Mining Company, Limited.	August 17, 1904	Trout Creek	100,000
The Western Salt Company, Limited	December 9, 1904	Mooretown	100,000
			$28,355,000

Licensed Mining Companies, 1904.

Name of Company.	Head Office in Canada.	Date.	Capital for use in Ontario.
			$
Ashland Emery Corundum Company	Ottawa	June 17, 1904	75,000
Big Master Mining Company	Gold Rock	October 5, 1904	300,000
Craig Mining Company	Bannockburn	February 13, 1904	50,000
Madoc Mining Company	Madoc	December 14, 1904	40,000
Minnehaha Mining and Smelting Company	Wabigoon	August 24, 1904	40,000
The Camp Bay Gold Mining Company of Ontario, Limited	Detroit, Mich. Rat Portage, Ont	October 26, 1904	100,000
The Detroit and Parry Sound Mining Company, Limited	Parry Sound	May 11, 1904	50,000
The Eldorado Mining Company	Rat Portage	June 30, 1904	50,000
The Leamington Oil Company, Limited	Leamington	December 30, 1903	100,000
The Pacific Coal and Oil Company, Limited	Toronto	May 11, 1904	17,500,000
Traverse City Gold Reef Company	Traverse City, Mich	March 16, 1904	2,800,000
Young's Lake Mining Company	Webbwood	April 20, 1904	50,000
			$21,155,000

MINING ACCIDENTS

The number of mining accidents in 1904 was less than in 1903, but the proportion of fatalities was greater, no less than seven men being killed out of a total of eleven casualties. The year was marked by one of the severest and most regrettable accidents in the history of mining in this Province, by which at the Shakespeare gold mine on the morning of August 2nd, six men went down to their death into the poisonous fumes of dynamite lingering at the bottom of the shaft after the setting off of a blast. A fuller account of this disaster is given below.

Canadian Copper Company.

At the Canadian Copper Company's works and mines at Copper Cliff four accidents happened during the year, resulting in the death of one man.

On March 30th Gaudense Dominick, an Italian, had his leg broken below the knee while helping to carry an "I" beam at the Ontario smelting works. In letting the beam down it rebounded, striking him on the leg and breaking it. As a result he was laid up in the hospital until some time in May.

On April 28th at 5.15 p. m., Isaac Isaacson, aged 22, and Mick Pentila, aged 18, two Finlanders employed at the Creighton mine, fell from a rock trestle and received serious injuries. Mick Pentila's injury consisted of a simple fracture of the left thigh, and a not very serious contusion of the knee of the same leg. In the case of Isaacson the injuries were more severe and resulted in his death the following day. He sustained a comminuted fracture of the skull in the left temple region, as well as a compound fracture of the left collar bone. An operation was performed in the hope of relieving the man's condition by trephining, removing and elevating the fractured and depressed bone. He was removed to the hospital at Copper Cliff, where he died about 2.30 p.m., April 29th. Mr. Thomas Oliver, coroner, held an inquest before a jury on April 30th, who returned a verdict of accidental death. The inquest brought out the fact that the two injured men were working on a rock trestle along with two others. The trestle was 25 feet high, with a railing three feet high on both sides. The two men were leaning against this railing, when it suddenly gave way, allowing them to fall to the rocks below. In the case of Pentila recovery took about ten weeks.

On the 22nd June, Joseph Yamary, while working in the Copper Cliff rock dump, slipped and fell, sustaining a fracture of the bones of the left forearm. He was taken to the hospital and laid up for a few weeks.

On 25th November, Andrew Dingler, a laborer in the rock house at Creighton mine, had his leg broken by being carried around a pulley, resulting from an attempt to throw a belt off the pulley with his foot. He sustained three fractures of the right leg below the knee. He was taken to the hospital at Copper Cliff.

Shakespeare Gold Mine

On 2nd August 1904 between 7 and 7.30 a.m., six men lost their lives at this mine by asphyxiation or poisoning, or both, from inhaling the "smoke" or gases, in the underground workings, resulting from a previous blast of dynamite. The deceased were N. Macmillan, superintendent, Peter Reed, engineer and blacksmith, Joseph Disley, Peter Grant, John Waters and Eli Latour, miners. An investigation into the circumstances surrounding this fatality was made by Mr. W. E. H. Carter, Inspector of Mines, whose report is substantially as follows:

The total force at the mine was seven, and only the seventh man, who worked on the surface was left alive. The former superintendent, Jas. Cronan, was however present at the time of the accident, and also W. E. Seelye, vice-president of the company, the Shakespeare Gold Mining Company, Limited. A number of outsiders from the adjacent Foley mine and the town, etc., were immediately summoned and quickly appeared on the scene. Mr. Macmillan had been in charge of the property from 22nd July, a period of 10 days. The mine workings measured as follows, at date of August 2nd 1904: Shaft, 95 feet deep, vertical, and 7 feet by 7 feet in size inside and to bottom of timbers (down to the tunnel or 53-foot level) and decreasing below this to about 6 feet by 6 feet in the rock at bottom. The tunnel, driven N. W. 75 feet, intersects the shaft at its face at 53 feet depth; and from the same level drifts run S. W. 43 feet and N. E. 37 feet, with a crosscut S. W. 17 feet from the face of the latter. The second level is at a depth of 90 feet, and consists merely of a crosscut running S. W. 33 feet, directly under the tunnel. The 4 or 5-foot sump at bottom of shaft is usually full of water, and was so on 2nd August. Entrance to the lower workings is by the tunnel and down hanging ladders in the shaft. The two shaft compartments have not been partitioned off. Hoisting is done by bucket and steam hoist engine.

The surface plant at the mine consists simply of a power house containing a 40- or 50-horse power boiler, the hoist engine and a 3-drill Ingersoll air compressor, all apparently in fair if not good working order.

There had been no night shift for a while previous to the 2nd August, the two crews of miners of two men each working on day shift only, one driving the second level S. W. crosscut, in the face of which the blasting was done which was the indirect cause of the accident; and the other the first level N. E. drift.

Following the usual custom, the blast was set off at the end of the shift, at about 5.30 p. m. There were five holes, and of these three were set off first by themselves at the above hour. The air was then blown in from the compressor until 6.30, or after supper, when one of the crew went down into the mine and set off the remaining two holes. The air hose was hung up in the shaft above the lower crosscut and remained there until next morning, no attempt being made to blow out the gas from this second round of holes. Now, in such cases as this, namely when blasting had been done subsequent to the last exit of the miners, the orders from the superintendent to the engineer were that the latter should blow out the smoke with air from the compressor for at least about 10 minutes, (no stated period specified and the order being to that extent indefinite) before the men went down to work in the morning again. If there was a night shift as well as day, with blasting at the end of each, the compressor was kept running for the hour or more between the two shifts blowing out the smoke and gases, the next shift finding the air good by the time they were ready to descend. This precaution had latterly, with the extension of the lower workings, been found necessary, because the natural draught, at all times very poor, could not be relied

upon to clarify the air. A strong draught prevails most of the time through the tunnel and up the upper half of the shaft; but this did not stir up any appreciable circulation of the air in the shaft and crosscut below the tunnel level. These facts appear to have been well known to the deceased men, particularly to the four miners who went down the workings first. It has also been shown that this portion of the shaft was blue with smoke, which should have been sufficient to deter men from entering before fresh air was supplied them.

On the morning of the accident the engineer, Peter Reed, had gone to the power house before breakfast and put a fire in the boiler so that steam was up to about 10 pounds at 7 a. m. But instead of returning there again before 7 a. m. and starting the compressor so that the men might have fresh air when they went down, he went over in company with the miners. Just at 7 a. m., as the whistle blew, the four miners went in the tunnel and descended the shaft. Only two should have gone down, since the other two were working in the drift on the tunnel level. It is not known why the whole four of them descended. However, on the way down they took the air hose from where it lay on the timbers just above this bottom crosscut and had time to carry it in to the face of this crosscut; but there one man dropped across it, and two dropped at the mouth of the crosscut and the fourth fell into the shaft sump, all overcome by the gas. Total paralysis or unconsciousness was not immediate; their shouting, or at least one shout, was heard from the power house at the mouth of the tunnel just after their descent, and on hearing it Reed and the other surface man rushed into the tunnel and heard the men groaning also. All signs of life disappeared, as nearly as can be ascertained, within one or two minutes of their descent, due no doubt of paralysis, followed by unconsciousness. Death itself would not necessarily follow for some minutes after, and had the men been raised to the surface within a short time they might even then have been rescusitated.

Reed, instead of rushing back again and starting the air compressor to give the men air, went down the ladders himself and fell off into the sump, overcome. It was probably then about 7.05 a.m. The superintendent, Mr. N. Macmillan, with Mr. Cronan, then arrived on the scene from the boarding house and in a few minutes—variously stated at from 10 to 15 minutes—the air compressor was put in operation and air blown below. The bucket in the shaft was at the same time raised and lowered continuously to help start an air current. Macmillan (about 7.20 a. m.) went in the tunnel again, and then he also went down the shaft, and, like the engineer, dropped off before reaching the bottom.

Cronan then took charge of things, and let down a second line of air hose; but not until about 10 a. m. did anyone venture to enter the workings again. The deceased men were then raised to the surface. Their appearance differed but little from when alive, according to the evidence of the bystanders. This leads to the belief that, besides carbonic acid gas and nitrogen, there was a relatively large percentage in the gases of carbon monoxide, which is a poison, alone producing unconsciousness immediately.

The remaining dynamite was not in the best of condition apparently (1) because since its arrival in December 1903 the boxes had not been once turned over, and this had caused the nitro-glycerine to partially settle to the lower side of the cartridges; and (2) because on account of leaks in the roof of the magazine, the upper layer or two of cartridges in each box had absorbed considerable water. The explosion of such dynamite in all probability would be attended with the generation of more smoke and gas than that from good, fresh dynamite, so that is is quite possible, if not likely, that the charge on the night previous to the accident produced an extra quantity of the injurious gases. The dynamite was made by the Ontario Powder Company, and, according to the evidence, has given satisfaction, the only misfires reported, according to James Cronan, being due to unexploded detonating caps.

Table of Mining Accidents 1904

No.	Date.	Mine or works.	Name of injured person.	Result of injury. Slight.	Serious.	Fatal.	Above ground.	Below ground.	Nature of injury.	Cause of accident.
1	Mar. 30	Canadian Copper Co.	Gaudense Dominick	....	1	....	1	....	Leg fractured	Struck on leg by beam.
2	Apr. 28	Canadian Copper Co., at Creighton mine.	Isaac Isaaeson	....	....	1	1	....	Skull fractured	Fall from rock trestle.
			Mick Pentila	....	1	....	1	....	Fracture of left thigh	
3	June 22	Canadian Copper Co.	Joseph Yamary	....	1	....	1	....	Arm broken	Fell on rock dump.
4	Aug. 2	Shakespeare Gold Mining Co.	N. Macmillan	....	....	1	....	1	Asphyxiation	Inhaling poisonous gases.
			Peter Reed	....	....	1	....	1		
			Joseph Disley	....	....	1	....	1		
			Peter Grant	....	....	1	....	1		
			John Waters	....	....	1	....	1		
			Eli Latour	....	....	1	....	1		
5	Nov. 25	Canadian Copper Co., at Creighton mine.	Andrew Dingler	....	1	...	1	....	Leg Broken	Carried around a pulley by belt.
		Total		....	4	7	5	6		

Total casualties, 11.

The bodies were removed and buried by the relatives of the deceased. No post mortem examination was made upon any one of them. This should have been done, however, for the determination if possible of the particular gas, if there was one in particular, and if not, then of all the gases, which caused death.

That death was due to inspiring noxious or poisonous gases cannot be doubted; nor that these gases were generated by the explosion of the charge of dynamite on the evening previous; and it is possible if not probable that the condition of the dynamite caused the formation of an undue percentage of these gases. The dynamite, however, cannot be blamed, since in its explosion these gases are always generated in dangerous quantities. The accident was due to the failure of the engineer, Peter Reed, to blow out the smoke and gases from the mine before the men went down, and to the carelessness of the men themselves in entering the workings before fresh air was blown in. Superintendent Macmillan, and also engineer Reed, sacrificed their lives in an effort to save their fellows, but unfortunately without any forethought, for otherwise they would have recognized the certainty of their own death in the course they took, and would have made more effectual efforts from the surface, where they were so badly needed.

THE DIAMOND DRILLS

The last operations of the "C" diamond drill in 1903 were in Dufferin county. In June of 1904 the drill was placed at the disposal of the Black Bay Mining Company to be used on their property in exploring for copper. This property is location McA 217 on the east side of Black bay, lake Superior, and is 46 miles from Port Arthur by boat. Considerable development work had already been done, a shaft having been sunk to a depth of over 100 feet. Some ore had been found up to this depth, when a sandstone formation was encountered. This property is described in the Thirteenth Report of the Bureau of Mines. It was thought that the ore body would be found again at a greater depth, so a vertical hole was drilled to a depth of 1,000 feet. The rocks traversed by the drill were chiefly amygdaloidal trap, sandstone, quartzite and conglomerate.

Only one hole was bored at a total cost of $1,033.82, or $1.03 per foot, and the net cost to the operators amounted to $672.00, or $0.67 per foot, while the gross cost of diamonds per foot was $0.28.

When drilling operations ceased at Black bay, the drill was moved to Port Arthur and thence to Loon lake, to be used by Wiley & Company, on lot 8 in the seventh concession of McTavish, District of Thunder Bay. This district has been described in the Twelfth Report of the Bureau of Mines, page 310.

The property has been prospected quite thoroughly by test pits, and three shafts had also been sunk to depths of 20, 25 and 30 feet respectively. The higher formation shows iron exposed without any taconite covering, but south of this the covering seems to grow thicker. Ore of fine quality is found where the taconite covering is lacking.

The special Committee on the Nomenclature and Correlation of the Geological Formations of the United States and Canada visited this area in 1904, and described the succession as follows: "The top series is the Keweenawan, here consisting of sandstone above and conglomerate below, with interbanded basic igneous flows. Below the Keweenawan is the Animikie. The Animikie here has in general rather flat dips, although locally they become somewhat steeper. At the base of this formation is a conglomerate, bearing fragments of the next underlying series—a graywacké slate."

Summary of Operations with Diamond Drills

Firm or company.	Location of drilling.	Kind of Mineral.	Rock drilled through.	Total depth drilled.	Total cost.	Total cost per foot.	Net cost.	Net cost per foot.	Gross cost of diamonds per foot.	Drill.
				ft.	$	$	$	$	$	
Black Bay Mining Co..	Location McA. 217, Black Bay	Copper..	Amygdaloidal trap, sandstone, quartzite and conglomerate	1,000	1,033 82	1 03	672 00	67	28	"C"
Wiley & Co.	Lot 8, concessions 7 and 9, township of McTavish, district of Thunder Bay	Iron	Taconyte, slate conglomerate, and greywacke	199.5	708 10	3 55	460 25	2 31	75	"C"
			Total	1,199.5	1,741.92	....	1132.25	....	....	
			Average	....	....	1.45	....	.94	.94	

Four diamond drill holes were sunk by Wiley & Company on their property having depths of 48, 60, 45½ and 46 feet respectively, or a total of 199½ feet.

The ore occurred underlying the taconite, and in some cases the ore and taconite occurred very regularly in layers. Underlying this formation conglomerate and graywacké were encountered.

The total cost of drilling 199.5 feet was $708.10, or $3.55 per foot, being a net cost to the operator of $460.25, or $2.31 per foot, and the gross cost of diamonds amounted to $0.75 per foot.

The "S" diamond drill was in operation in Parry Sound District near Burk's Falls until February of 1904. An account of this is given in last year's Report of the Bureau of Mines.

In September the drill was sent to the northeast arm of lake Temagami to bore for iron for Mr. T. B. Caldwell, *et al.* The iron in this district is a magnetite, generally interbanded or closely associated with jasper. A description of the iron ore of the district surrounding lake Temagami is found in the Tenth Report of the Bureau of Mines.

Iron ore was reported to have been discovered in the vicinity of this lake in the autumn of 1899. Little however was done for some time, owing to the lands lying within the Temagami Forest Reserve. In 1902 regulations were passed allowing prospecting for minerals in the Reserve. Also, the building of the Temiskaming and Northern Ontario railway made the deposits easy of access.

Great difficulty was encountered in drilling. At a depth of 194 feet a cavity was encountered, from which there was a very heavy flow of water. The cavity also contained loose and broken boulders of chert. The hole was reamed to a diameter of two inches, and casing inserted, but it was found impossible to drive owing to the number of boulders. The hole was, therefore, abandoned. The rocks passed through were greenstone, diorite and chert.

The total cost of drilling, exclusive of the operations at Lake Temagami, was $1,741.92, or $1.45 per foot, the net cost to the operators being $1,132.25, or $0.94 per foot, while the gross cost of diamonds per foot was $0.94.

Owing to the late season, drilling was abandoned for the time.

PROVINCIAL ASSAY OFFICE

Mr. A. G. Burrows, in charge of the Provincial Assay Office, Belleville, furnishes the following report of its operations in 1904:

The Provincial Assay Office was established in 1898, by the Ontario Government, with a view of aiding the mineral development of the Province. Since this time it has been of much convenience to the public, affording facilities for obtaining reliable and independent examination of materials at reasonable rates.

The samples for examination are chiefly from the newer portions of the Province, where the search for mineral wealth is more active than in the older parts. During the past year that portion of Ontario along the line of the Temiskaming and Northern Ontario railway has been partially explored, and various ores of great value have been found. Besides the silver-nickel-cobalt deposits, copper and iron ores have been located, and samples of these have been examined at the office. Increased activity in iron exploration in Rainy River district, has proved the presence of valuable iron deposits. Samples analyzed at the office were very promising. Some of these are high in sulphur, but many are of Bessemer grade. As in former years the bulk of gold ore samples came from western Ontario, with occasional samples from other parts. The copper ores were chiefly from the region between Sault Ste. Marie and Parry Sound.

Other materials examined were zinc, lead, molybdenum and nickel ores, limestones and clays, corundum, sulphur and arsenic ores, besides some artifical products.

During the year 792 samples were analyzed in whole or part, giving the percentages of metal, etc.; while 173 specimens were reported on as to commercial value, being identified either by hand examination or qualitative methods. The analytical work is checked off in duplicate to minimize the chance of error in issuing certificates.

Work for Bureau of Mines

The following services have been performed for the Bureau during the year:

(a) Issuing reports on samples collected by government geologists during their summer's explorations. The material submitted included:

(1) Iron ores from the iron ranges of Michipicoten district.

(2) Cobalt-silver-nickel ores from the vicinity of Cobalt. Besides making many analyses of the various ores of the district, special attention was given to working out the chemical composition of many of the accessory minerals, which have a scientific interest. These are referred to in Prof. Miller's reports on this region.

(3) Peat samples from northern Algoma and Nipissing. On analysis, these proved to be of fine quality and suitable for the manufacture of peat fuel.

(b) Issuing check reports on pulped samples of iron ore raised and smelted in Ontario, on which it was proposed to claim the bounty provided by the Iron Mining Fund.

(c) Additional analyses of limestones, for report on the limestone industry of the Province. Some of the samples were found to be of great purity, so that material is at hand for any of the purposes for which quality is required, such as sugar refining, paper manufacture, cement, etc.

Work for Private Parties

The following services have been performed for the public, during the year:

(a) Issuing reports, consisting of assays, analysis, identifications and other commercial tests. While a fee on a reduced scale is charged for the work, it is required that it be paid before certificates are issued.

(b) Supplying information where possible to owners of mineral lands and others, who desire to be placed in touch with purchasers, and also advising as to value, uses, etc., of their materials.

(c) Making check determinations and control assays, in case of disputes as to correct values.

(d) Sending samples of ores and minerals to parties desiring to use them for comparison in prospecting.

The varied nature of the analytical work required of the office during the year may be seen from the following list of determinations.

Assays.	For Bureau.	For Public.	Total.
Gold (amalgamation)	2	4	6
Gold (fire assay)	43	428	471
Silver	50	143	193
Platinum	2	14	16
Cobalt	20	7	27
Nickel	20	32	52
Copper	12	62	74
Manganese	1	7	8
Bismuth	2	0	2
Molybdenum	1	4	5
Zinc	4	8	12
Lead	4	10	14
Tin	1	1	2
Arsenic	17	2	19
Antimony	4	0	4
Total	183	722	905

Analyses.			
Metallic iron	76	28	104
Alumina	91	38	129
Silica	95	23	118
Lime	93	17	110
Magnesia	93	15	108
Ferric oxide	79	15	94
Ferrous oxide	6	2	8
Sulphur	136	34	170
Moisture	78	8	86
Alkalies	62	12	74
Organic	37	0	37
Phosphorus	40	10	50
Titanium	13	10	23
Miscellaneous	197	32	229
Total	1,096	244	1,340

Total Assays	905
" Analyses	1,340
" Identifications	172
Total Determinations	2,417

Location

The office is located in the city of Belleville, on Victoria avenue, and is housed in a two-storey brick building. The lower floor is utilized as an office, with grinding room in the rear, while the upper floor is devoted to analytical purposes. The laboratory is equipped for making all mineral analyses.

Methods

The following methods are used:

Gold and silver (1) by fire assay, using gasoline for fuel. Owing to the great variety of ores treated, it is found more satisfactory to roast all ores containing sulphur and arsenic, rather than attempt to eliminate these elements during fusion. Two furnaces are used, a large Hoskins for making a number of assays at a time, and a smaller one for limited work. An assay balance, sensitive to one one-hundredth of a milligram is used for weighing the beads and residues. (2) By amalgamation, to test the free milling character of the ore.

Platinum: By fire assay.

Copper: By cyanide titration, and electrolytic methods.

Nickel and cobalt: By electrolytic method. For this purpose a set of potash cells (Edison Primary) is used. The metals are plated together, and afterwards separated by dissolving, and precipitating cobalt as potassic cobaltic nitrite.

Lead: By ammonium molybdate titration method.

Zinc: By titration with potassium ferrocyanide.

Other determinations are made by standard methods.

All samples are pulped to 100-mesh, and those requiring finer reduction are ground in an agate mortar to an impalpable powder. Wet ores are dried at 100 C. and analysis reported at that temperature. In other cases the analysis is reported at ordinary temperature.

Notes

Samples brought personally to the office are examined free of charge, except where quantitative work is desired. Circulars of rates, sample bags and mailing envelopes are supplied to those desiring to send in samples.

One laboratory assistant was employed during the year. Mr. G. H. Hambly acted as assistant till first of October, when he left to accept a position in the chemical laboratory at Helen mine, Michipicoten.

Fees amounting to $830.30 were collected and remitted to the Bureau of Mines.

MINING AGENCIES

Sudbury

Mr. T. J. Ryan, Crown Lands and Mining Agent at Sudbury, makes the following report:

I beg to submit a short account of the workings of the Mining Lands agency at Sudbury during the year 1904.

The Mining agency, which is carried on in conjunction with the Crown Lands agency, with 29 townships open to prospectors, was opened in 1900. In 1901, 1902 and 1903, there was great activity in prospecting and taking up mining lands. During some of these years this agency sent in applications for over 15,000 acres, and paid in over $2,100 in cash in the year on account of mining lands.

The year 1904 was less active. This was partly due to the short and very rainy season, making it almost impossible to use the tote roads and trails, especially in low lands. Another reason was the fact that many of the prospectors were attracted to the new Temiskaming country, along the Government line of railway, by the discovery of rich deposits of cobalt, nickel, arsenic and silver ores. All applications would go in from the agency in that district, or direct to the Department at Toronto.

This Mining agency is extensively used from all parts of the district by prospectors and others, both by letter and personally by use of the Land Roll open to every person free of charge. Mining maps, reports, Mines Acts, blank forms of affidavits and applications, etc., are all kept on hand and furnished free or mailed to prospectors who cannot get in. The map issued by the Department of the "Sudbury Nickel District" is always in demand.

However, operations with the mining companies in the district have been active, especially with The Huronian Company, where the work in developing water power on the Spanish river has been of a gigantic nature. The North Star mine also changed hands to the Mond Nickel Company, and is being actively developed, with entirely gratifying results.

The year 1905 will see a great revolution in mining here, when the water power companies commence to generate electricity.

The summer mining schools or classes conducted here each year give satisfaction and are a great benefit to prospectors and others. The Provincial Assay Office has been of splendid service to prospectors and those who want to obtain reliable reports on their finds.

Rat Portage

Mr. N. Seegmiller, Mining Agent at Rat Portage, reports as follows:

I beg leave to submit the following report covering the work of this office with regard to mining lands for the year 1904.

A great many inquiries were received for information about the mining lands and minerals of this district, all of which received careful attention. Maps and reports of the Bureau of Mines were furnished upon request.

Very few new locations were taken up during the year and but few properties were worked. The Eagle Lake district was fairly active, most of the exploring and development work being done there. In the Lake of the Woods district the Sultana, Black Eagle, Golden Horn and Olympia mines did considerable work and were visited by American and foreign capitalists.

The receipts of this office were derived chiefly from rentals and the sale of leased lands.

Enquiries were received about the country lying north of the Canadian Pacific Railway along the proposed route of the new transcontinental line, but as no authentic maps of this territory are available and but little known of its mineral resources, not

much information could be given. This part of the Province no doubt will receive a great deal of attention during the coming summer.

Michipicoten Mining Division

Mr. D. G. Boyd reports as follows:

The year 1904 was the quietest, both as regards the staking of claims and development of prospects, in the history of the district. Owing to the continued dulness, the local office was closed at the end of July, and the business was thenceforward carried on from Toronto.

The total number of licenses issued during the year was 89, and the number of claims registered 70, while the total amount of fees received was $1,504.

Little was done in the way of actual mining except at the Helen iron mine, which resumed operations in July, and continued steadily at work for the remainder of the year.

Appended is a list of licensees, giving place of residence, number of license and number of claims (if any) registered during the year. Where not otherwise indicated, the licensees are residents of Ontario.

License.	Residence.	No. of License.	No. of Claims.
Abbott, S. G.	S. S. Marie, Mich.	1419	
Armstrong, T. H.	Michipicoten River	1458	1581
Barr, W. C.	S. S. Marie	1491	1608
Barton, S.	Michipicoten River	1478	1582
Beebe, W. D.	Titusville, Pa.	1464	1577
Begg, T. J.	White River	1465	
Blackinton, A. B.	S. S. Marie	1431	
Brown, E.	"	1448	1572
Brown, Marie	"	1462	1591
Brundage, J. M.	"	1441	1562
Carleton, C. C.	S. S. Marie, Mich.	1454	1620
Carr, J.	Michipicoten River	1480	
Chappelle, B.	Onaway, Mich.	1417	
Chisholm, D. H.	S. S. Marie	1488	1599 1603
Connors, J.	S. S. Marie, Mich.	1476	1585
Davis, L. H.	S. S. Marie	1493	1617, 1618, 1619
Dawson, P. U. B.	"	1494	1601
Dickson, J. L.	Michipicoten River	1471	1565, 1566
Donoghue, T.	S. S. Marie	1487	1598, 1604
Doore, W. E.	S. S. Marie, Mich.	1443	
Doyle, J. P.	Wawa	1418	1558
Dycie, J. G.	Michipicoten River	1423	1557
Dycie, M.	" "	1416	1556, 1559, 1578
Eldridge, R. C.	S. S. Marie, Mich.	1481	
Everett, W. C.	S. S. Marie	1442	
Godon, A.	Missanabie	1452	
Godon, J.	"	1453	
Godon, P.	"	1434	
Goetz, A.	S. S. Marie, Mich.	1438	1583
Goetz, G.	" "	1445	1586
Goetz, J.	" "	1440	1584
Goetz, M.	" "	1446	
Goetz, R.	" "	1439	1587
Gravel, A.	Wawa	1470	1590
Grover, M. B.	S. S. Marie	1469	
Hecox, C. W.	S. S. Marie, Mich.	1455	1621
Hodgson, J. V.	S. S. Marie	1482	1595, 1605
Holbrook, H. B.	Michipicoten River	1449	1570
Hunt, J.	" "	1503	1574
Irving, J. E.	S. S. Marie	1492	1600, 1606
Johnson, J. B.	Michipicoten River	1473	
Jones, C. H.	S. S. Marie	1485	1609
Kennedy, T. J.	S. S. Marie	1484	1597, 1602
Kitchi Gammi Gold Mng. Co., Limited	"	1415	

License.	Residence.	No. of License.	No. of Claims.
Legge, C. H.	Gananoque	1506	
Legge, J.	"	1505	
Lemieux, M. C.	Wawa	1459	1575
Letellier, J. T.	"	1429	
Martin, F. J. S.	S. S. Marie	1497	1593
May, E	Michipicoten River	1437	
Michael, G. F.	S. S. Marie	1436	
Miller, E. H.	St. Thomas	1428	
Miller, G. L.	"	1427	
Miller, J. M.	"	1426	
Miller, R. J.	"	1425	
Murray, T. H.	S. S. Marie	1496	1594
McDonald, M. F.	S. S. Marie, Mich	1420	
McDougall, L.	White River	1502	
McDougall, W. H.	"	1451	
McPhail, D. P.	S. S. Marie	1498	
Newton, E. L.	S. S. Marie, Mich	1475	1589
Newton, H. L.	" "	1474	1588
Orchard, F	S S. Marie	1433	1561
Parks, G. F.	Marysville, Cal	1467	
Plummer, H. L.	S. S. Marie	1468	
Pononish, A.	White River	1450	
Pratt, W.	Michipicoten River	1472	1580
Premier Gold Mining Co.	St. Thomas	1507	
Reed, G.	Michipicoten River	1500	1569
Reed, S.	" "	1501	1568
Riberg, J	S. S. Marie, Mich	1463	1576
Sayles, C. N.	S. S. Marie, Mich	1430	1622
Shafer, F.	" "	1435	
Stolle, H. H.	Tripoli, Wis	1479	1579
Touchette, J.	Missanabie	1421	
Towers, H. H.	S. S. Marie	1495	1592
Towers, T. A. P.	"	1447	1571
Travis, R. L.	Michipicoten River	1444	1567
Trotter, A	S. S. Marie	1432	1563
Trotter, T. W.	"	1424	1564
Walker, G. H.	Wawa	1466	
Warren, S.	S. S. Marie	1486	1610, 1614
Webster, W.	S. S. Marie, Mich	1456	1623
Wilde J. A.	S. S. Marie	1483	1596, 1607
Willmott, A. B.	"	1490	1615, 1616
Wright, K.	"	1499	
Wynn, J. S.	"	1489	1611, 1612, 1613

SUMMER MINING CLASSES

BY W. L. GOODWIN

Itinerary

Preparations were begun on April 29th. Although large quantities of minerals have been collected for the purpose, it was still found necessary to purchase a few to fill out gaps in the collections. Instead of carrying the whole outfit of minerals from place to place, a box was made up for each place, and sent by express from Kingston about a week before the date of beginning the class. In this way the luggage was reduced, and much labor was saved in packing and unpacking. It also made the luggage more manageable in cases where portaging was necessary.

The writer left Kingston May 2nd, accompanied by Herbert Van Winckel, and camped that night at the pyrite mine of the Madoc Mining Company, near Bannockburn. The journey was made via Grand Trunk railway to Trenton, and thence by Central Ontario railway to Bannockburn, from which place a drive of two miles brought us to the mine. The class was opened on Tuesday, May 3rd, in the "dry" fitted up by the company for the purpose. It was closed on Saturday, May 7th. On Monday, May 9th, I left for Parham Station via Kingston, where a few hours were spent in completing preparations for the summer's work. I left Kingston by the Kingston and Pembroke railway on Tuesday, May 10th, and arrived at Long Lake zinc mine (Jas. Richardson & Sons) on the same evening. The class was opened at 6 p. m. on Wednesday, May 11th, in the dining room. On Friday, May 13th, I was joined by Mr. J. Watson Bain, of the School of Practical Science, Toronto, who took part in the work of the classes from that time forward. The class at Long Lake was closed on Tuesday, May 17th. On Wednesday, May 18th, we proceeded to Eganville via Renfrew and Canada Atlantic railway. Arriving there on Thursday, we were met by Mr. D. J. McCuan, manager of the Radnor iron mine. He drove us out to the mine about eight miles southeast of Eganville. The class was opened at 6.30 on the same day, and closed on Wednesday, May 25th. Returning to Eganville we continued the journey by the C. A. R. to Barry's Bay, thence by steamer *Hudson* to Combermere, whence the steamer of the Canada Corundum Company carried us to Craigmont. The class was opened there at 6.45 p. m. on Friday, May 27th, and closed on Thursday, June 2nd. On Friday, June 3rd, the company's boat *Ruby* carried us to Barry's Bay. Here we took train for Mattawa via Renfrew, and arrived on Saturday, June 4th. There the Ottawa branch of the C. P. R. was followed up to Temiskaming, whence the steamer Meteor took us to Haileybury. The class was opened there on Monday, June 6th. On Tuesday Mr. Bain opened a class at New Liskeard, four miles north, where he carried on the work for four days. The class at Haileybury was closed on Saturday, June 11th. Monday, June 13th, was spent in collecting niccolite and smaltite five miles south of Haileybury. We left by steamer Meteor on Tuesday, June 14th, just in time to escape the smallpox quarantine. We arrived at Sudbury on Wednesday, June 15th, and drove on the same day to the Creighton mine, twelve miles, stopping at Copper Cliff to pick up the box of mineral specimens which had been expressed on from Kingston. At Copper Cliff we met the president, Mr. A. P. Turner, who made arrangements for the class at the Creighton, and then showed us over the new works now approaching completion. Opened the class at 7 p. m. on the same evening, and closed it on Tuesday, June 21st. The next morning, we drove to Copper Cliff station, and took train for Massey station, where we engaged Mr. Campbell, liveryman, to

drive us to the mine, five miles. Captain Sommers was in charge in the absence of Messrs. Errington and Barclay. The class was opened on Thursday, June 23rd, and closed on Tuesday, June 28th. On Wednesday we proceeded to Sault Ste. Marie, but found that the Algoma Central train did not leave for Superior mine until Friday morning. We were therefore obliged to spend Thursday at the Sault. On Friday, July 1st, the journey was resumed. At Superior Station, 40 miles from the Sault, we found the mine wagon waiting for us as arranged by the manager, Mr. Frank Perry. The mine is four miles from the station, and the road being rough, the journey was very slow. Capt. Derry made us welcome, and the class was begun the same evening. The work was completed on Friday morning, July 8th, and the mine wagon took the luggage to the station in the afternoon. Walking out, we caught the train and arrived at Sault Ste. Marie in the evening. We proceeded by C. P. R. steamer Manitoba to Port Arthur, arriving there on Monday, July 11th. Mr. T. R. Jones, manager of A L 282, now called the Sunbeam, arranged for our transportation, and we took the Canadian Northern express to Atikokan station, 142 miles from Port Arthur. Having slept there, we took the local returning east on the morning of July 12th, and reached the Hospital, only to find that the packers had left. However, under the energetic guidance of Pete Dugal, we hurried after them, and found them on the long portage between lakes Sabawe and Asinawe. They (Marcotte and Lepine) returned with us to the Hospital, and took charge of the luggage. The distance to the mine is thirteen miles by canoe, with five portages, most of them very short. The mine was reached too late to start the class that evening. On Wednesday, July 13th, work was begun, and continued until Wednesday, July 20th. On Wednesday, July 20th, we left the Sunbeam by canoe and reached Hematite Hospital at noon. Took the local train to Atikokan, slept there, and caught the express for Port Arthur next morning. We left Port Arthur that evening by the C. P. R., but, as the train did not stop at Wabigoon, we were obliged to spend the night at Ignace, and go on by the local next morning. On arriving at Wabigoon three hours late, we were delighted to find the Galatea still waiting for us. A telegram from Ignace had this happy result. Leaving Wabigoon at 2.30 p. m., we reached Beaudro's Landing at 6.30, and after tea took stage over the Government road (still in very bad condition) to Gold Rock. Arriving there late at night passengers found it hard to get a place to sleep. But "a friend in need," Mr. Harry Rhodes, gave us his bed over the Wabigoon Trading Company's store, and we found this very much more comfortable than the floor of the station at Ignace. Next day (Friday, July 22nd) the class was opened at the camp (H P 371) of the Twentieth Century Company, about ½ mile east of Gold Rock. The class was closed on Thursday, July 28th. The return journey was then made. I arrived at Kingston on Monday, August 1st.

Eleven places were visited during the summer, and the classes in all of these were unusually well attended. The total number in attendance was 518. The number of specimens distributed was about 16,000. As on former occasions many mineral specimens were identified for members of the classes. The conditions of life are improving in the mining camps. This is very noticeable in the food, the efforts to have good clean sleeping quarters, and the more general presence of reading matter. Managers in most cases offer every inducement to married men to bring in their families. Comfortable houses are often built for them by the company, or in some cases the company supplies the logs for houses which the men build in their spare hours.

A feature of the work during the summer of 1904 was the lectures on geological, mining and kindred subjects, illustrated by lantern slides. The lantern used was a portable acetylene generator and lantern manufactured by D. T. Thompson and Company of Boston. It was found possible to take it with us to the most out of the way places. The lectures were uniformly well attended, and were always listened to with the greatest attention. A larger collection of slides should be provided for this work.

BANNOCKBURN PYRITE MINE

This mine is situated about two miles south of the village of Bannockburn. There were thirty-five on the pay roll, and of these thirty-three attended the class, with an average attendance of twenty-five. The acetylene lantern, purchased for these classes, was first brought into use here to illustrate a number of lectures given at the close of each days's study of the mineral specimens. It answered the purpose admirably, and four lectures were given on geological and mining subjects. The class was held outdoors at 6 p. m., when both shifts were at the mine. This was found to be a very convenient arrangement for this place, as the men boarded in many cases at farm houses some distance away and preferred to have the class before going home to tea. The attendance was remarkably good, and the intelligent questions asked showed that the men were appreciative. A quantity of pyrite was collected for future use.

On May 5th I drove to the lead mine of the Ontario Mining and Smelting Company, about two miles north of Bannockburn. The manager, Mr. H. E. Gamm, kindly allowed me to box up a large quantity of the beautiful galena for use in the summer classes. Here also a little marcasite was collected, and a number of specimens of galena covered with anglesite. The vein is narrow but of solid galena, with beautiful cleavage. It was worked by another company for several years, and the dump is now being profitably jigged. There is a good crushing and concentrating plant, and a reverberatory smelter. A blast furnace is being built.

On May 6th I drove to Eldorado and collected hematite, specular ore and quartz geodes coated with hematite crystals. On May 7th I walked to Shaw's farm about a mile west to see a copper pyrite prospect, which has been opened up for several years.

OLDEN ZINC MINE

Here much trouble had been experienced from water which came in through a large water course. This had been partially cemented up, and the foreman, Mr. T. Flynn, was confident that the stream, which flowed only in wet weather, could be completely checked by careful cementing. The shaft had been sunk to 160 feet when it was flooded out. In the meantime good ore was being raised farther east on the vein. The seconds accumulated since mining began were being hand-jigged, and a clean product obtained. There were fourteen men on the pay-roll when the class was held. Here also the hour was made 6 p. m., and found to be very satisfactory. The class was held out doors, and the lectures in the sleeping camp. Both were attended by a number of people from the farms in the vicinity. A special lecture was given one evening for the farmers and their families. The total attendance at the class was thirty-three, with an average attendance of twenty-five. Sixty-five attended the lectures, which were illustrated by about 300 lantern slides.

RADNOR IRON MINE

The manager, Mr. D. J. McCuan, met us at Eganville and kindly provided transportation to the mine, about eight miles in a southeasterly direction. The company was completing a good wagon road from the mine out to Caldwell on the Canada Atlantic railway. The miners at the Radnor are mostly drawn from the surrounding farms, but a few familiar faces were noticed of old Lake of the Woods men. There were thirty-three men employed, and they attended the class and lectures almost to a man. On May 24th a number of people drove to the mine from Eganville, Caldwell and other places in the neighborhood. Mr. T. Davis, of Eganville, brought a large number of specimens for identification, including molybdenite, graphite, corundum, feldspar, calcite, hornblende and sphene. A special lecture on crystals and crystallization was given to these visitors at 4.45 p. m. Twenty-five were present. The total

attendance at the class was forty, and the average attendance twenty-eight. The attendance at the lectures was about the same. Our stay at the Radnor was made particularly comfortable by the kindness of the manager and the chemist, Mr. C. M. Campbell, B. Sc.

CRAIGMONT

Here we were received cordially by the manager, Mr. D. G. Kerr, who had our boxes transferred, and made us his guests during our stay in the corundum region. There were about 150 men on the pay-roll, but most of them spoke little or no English, and many of the English-speaking miners lived at some distance from the mines. These difficulties made it impossible to organize a large class. The meetings were held in one of the large dining rooms (Dennison's) near the large new mill which had just been completed. The total attendance was about sixty, and the average attendance twenty-four. Many men who could not attend the class got complete named sets of specimens with such explanations as could be given in a short time. One man (Quod) came from Quodville, fifteen miles away to consult us about specimens of pyrrhotite and graphite. He had seen the notice of the classes in the newspapers.

HAILEYBURY

The discovery of nickel, silver and cobalt ores five miles to the south of this town, on the line of the Temiskaming and Northern Ontario railway, had stimulated interest in minerals, and the opportunity to study them practically and systematically was particularly welcome. A few leading citizens engaged the Orange Hall as the place of meeting. The population of Haileybury is about 600, but there is a large floating population of lumbermen and railway men. Prospecting was going on vigorously around the new discoveries, but the difficulties encountered were serious, owing to the heavy blanket of moss and gravel. Several of the prospectors walked every day distances of five or six miles to attend the class and lectures. There was a total attendance of about eighty-five, and an average attendance of thirty-eight. Many sets of minerals were given to men who could not attend the class. Prospectors showed specimens of galena, copper pyrite, and magnetite found in the neighborhood. Copper pyrite has been discovered on Fernholm's farm about two miles south. On June 8th I walked to Cobalt station (the name proposed by Prof. W. G. Miller for the new mining camp) in the company of Mr. Earle (of New York), buyer of ores, the Russels, engineers, Galbraith, division engineer, A. Ferland, proprietor of the Matabanick hotel and part owner of the smaltite vein, S. Ferland, prospector, and Hebert, discoverer of the native silver vein (No. 3). An incident of this trip is worth recording as illustrating one of the dangers of a prospector's life. As some of the party were walking towards the railway construction camp they noticed a falling tree crash down across the middle of a small tent. On examination S. Ferland was found inside, but unhurt! He had moved to one end of the tent just as the tree fell. On June 11th Professor Sharp (late of Morrin College) drove over from his farm near New Liskeard and took me back, a pleasant drive through the woods. There is a small outcrop of magnetite and hematite near Professor Sharp's house. June 13th was devoted to collecting specimens of niccolite, smaltite, and native silver, in connection with which mention should be made of the generosity of Messrs. Ferland, Timmins, Le Heup, Chambers and Darragh, who gave us a free hand among their valuable properties. We enjoyed the hospitality of Professor Miller's camp and the company for one evening of a dozen prospectors.

NEW LISKEARD

On Monday, June 6th, Mr. C. C. Farr took us from Haileybury to New Liskeard in his gasoline launch, thus avoiding a journey over a road almost impassable after the

long rains which had prevailed. There we met Mr. John Armstrong, and arranged for a class to be held in the Orange Hall, which was engaged for the purpose by the council. Professor Sharp, Rev. Mr. Pitts, and Mr. McCamus gave assistance which was much appreciated. The next day Mr. Bain, taking the lantern and the necessary mineral specimens, drove to New Liskeard and opened the class. The attendance was large and enthusiastic at both class and lectures. At the close of the work there, a number suggested that a more extended course should be given next year. The total attendance was about eighty, and the average fifty-one. Thanks are due the authorities of the Presbyterian church for the use of their building one evening when the Orange Hall was not available.

CREIGHTON MINE

Here we were the guests of the manager, Mr. George Sprecher. The class was held in a new log house, which proved comfortable for the purpose. There were about two hundred men on the pay roll, but only about forty of these were English-speaking. There was a school attended by about thirty children. A resident physician, Dr. McGonigle, had been added to the staff. A considerable village had grown up, many of the men having brought in their families. There were two general stores, and the daily train to Sudbury affords easy communication with the outside world. Altogether, the Creighton is being made a first-rate permanent mining camp. The total attendance was about forty, and the average attendance twenty.

MASSEY COPPER MINE

The class was held in the old log office, and was attended much better than last summer. The men were seated on rough seats improvised on the verandah while receiving instruction on minerals. When this was completed, the class moved into the darkened office for the lantern lectures. There were twenty-four men employed at the time of our visit. The total attendance was about thirty, including some men from the Hermina mine about two miles west, and a few farmers not working at the Massey mine. The average attendance was fifteen. Everything possible was done by manager Joseph Errington and superintendent R. C. Barclay to assist us in making the class a success.

THE SUPERIOR MINE

Having met Mr. Frank Perry, the manager, at Sault Ste. Marie, arrangements were made to proceed to Superior station, where the company's pack wagon met us and took the luggage to the mine. Captain Philip Derry welcomed us and made us comfortable during our stay at the Superior. The class was held out of doors and the lectures in the sleeping camp. There were eighteen men employed. All attended who were not at work at the time of the class. Mr. J. L. Naylor came from Searchmont to see the mineral specimens. He got a named set and the mineral indicator. Several of the mine employees whose occupations prevented their attending the class were given sets, with such information as could be mastered in the time at their disposal. Many of the men are experienced prospectors and most are good woodsmen. In this camp the interest in both mineral lessons and lectures was unusually marked. The region abounds in small lakes, in many of which speckled trout can be caught. The woods are mostly hardwood, and very open and park-like, making walking unusually easy. The total attendance was nineteen, and the average attendance fifteen.

SUNBEAM MINE (A L 282)

Here we found Mr. Copeland, the engineer, in charge, in the absence of Mr. W Jones, mine superintendent. We were hospitably entertained during our visit at the mine. The class was held out of doors and the lectures in the sleeping camp. A 10-stamp

mine. The class was held out of doors and the lectures in the sleeping camp. A 10-stamp mill had just been completed and the stamps had begun to drop on the day of our arrival. The mill, built near the bank of the Seine river, is connected with the mine, a distance of 3,200 feet, by a horse tram, by which the ore is conveyed. As the vein dips at 50° and the shaft is vertical for the first 68 feet, a raise was being made along the vein to the surface so as to give a straight shaft on the incline. This was nearly completed. The shaft was down 400 feet. There were thirty men on the pay roll, of whom twelve were non-English. Most of those of foreign birth attended both class and lectures. They included Finns, Swedes and Italians. Some of those of foreign nationality spoke English very well; others very imperfectly. All attended the class. The total attendance was thirty-one, and the average attendance twenty-three.

The difficulties of transportation are very marked in the case of this mine, making the cost of getting in supplies almost prohibitive.

LAURENTIAN MINE

This is a new prospect, being developed by the Twentieth Century Company. It is about half a mile east of Gold Rock on H P 371. Work was begun in November 1903 on a vein of well mineralized quartz and schist, striking about northeast and dipping at about 75°. The vein has been traced eastward to 298 and westward to the Big Master. At the time of our visit the shaft was down 125 feet and at the first level (80 feet) about 50 feet of drifting had been done. A crosscut had been made to a second vein about 20 feet to the eastward. Several other veins have been located on the property, including one which is claimed to be an extension of the Jubilee vein. The buildings included a temporary hoist house, a large and comfortable sleeping camp, a good dining camp, and three dwelling houses for the staff; also office, stable, store house, and power house. In February the stamp mill and other buildings at the Twentieth Century mine were dismantled and brought to the new location. Work is now being pushed on the foundation for the stamp mill and concentrating plant. The concentrates may be treated by cyaniding. Some very rich masses of ore have been taken out.

About two miles northeast, near the end of Mud lake, is the Volcanic Reef mine (S 40), near the Little Master, and owned by the Twentieth Century Company. It is a small quartz vein, with iron pyrites and shows of gold. A shaft has been put down 100 feet, and camp buildings were under construction. Thirteen men were employed.

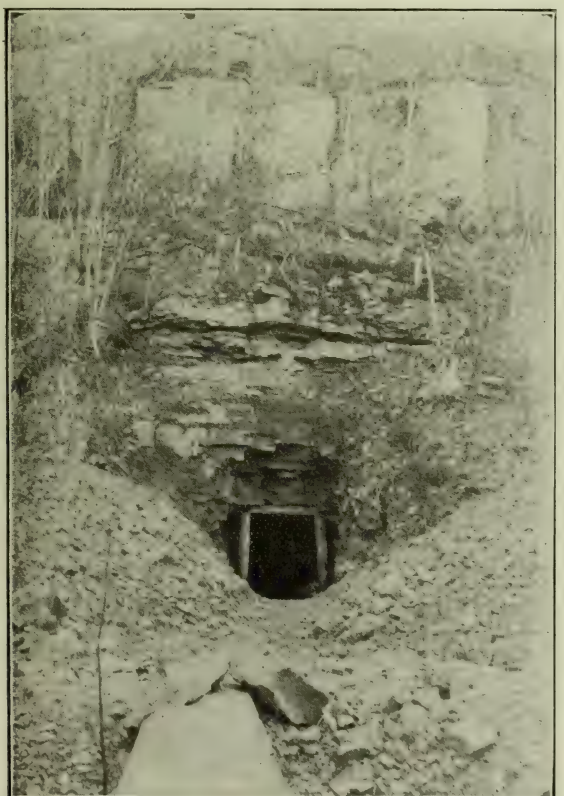
The class was held at the Laurentian, but several of the men walked over from the Volcanic Reef. As in the case of most of the mines visited this summer, the class was carried on comfortably out of doors. The lectures were given in the new sleeping camp. The total number in attendance was forty, and the average attendance twenty-two.

Both properties of the Twentieth Century Company were being developed under the management of Mr. Dryden Smith.

MINES OF WESTERN ONTARIO

BY W. E. H. CARTER

In the mining of gold, for which the western portion of the Province has been chiefly noted, results have been somewhat disappointing. The number of properties working has not greatly decreased, but the energy expended thereon has. The reasons most apparent for this state of affairs have been so frequently touched on in these reports that they need not be again gone into. Suffice it to say, that if capital were



McConnell's Iron Claim, Animikie Range. Tunnel in hematite; slate overlying, 4 to 5 feet, diabase laccolites on top.

concentrated in a few good prospects instead of being dispersed among a great many small weak companies to be spent on more or less unlikely veins, the production of the precious metal from this part of the country would be greater than it is.

A number of stamp mills have within the year been erected, but as has been pointed out on other occasions with emphasis, the work done in the mine is not always sufficient to warrant such expenditure. The haste for dividends is the bane of the industry.

Interest in this western mining field has latterly been turning to other ores, chiefly iron and iron pyrites, deposits of both of which will shortly be turned into producing mines. Not much additional news can be reported regarding the iron of the Atikokan and Steep Rock lake districts, but sufficient ore is already there to ensure production on a good scale.

A few miles east of Port Arthur, at Loon Lake siding on the Canadian Pacific Railway, the long-known but unappreciated and untouched hematite deposits have been energetically explored by diamond drills and mining during the past year or two with great results. The ore in sight, both high and low grade, is estimated at a very considerable quantity. The important possibilities of all these deposits have not been overlooked, as shown by the recent incorporation of a strong company of railway and iron capitalists to erect in the immediate future a blast furnace at Port Arthur to reduce these ores.

Animikie Iron Range, upper ore bed (all ore in view, 35 per cent. Fe) R. McConnell's location, 59 B.

The strike of high-grade Bessemer hematite at the Williams mine is another indication of the resources of the region. This ore is now being smelted at the Lake Superior Corporation's blast furnaces at Sault Ste. Marie, Ont .

The straight copper deposits are also receiving a fair share of attention, and by the perseverance of a few owners we may shortly see a number of profitably working mines, a thing unknown since the Bruce mines were in active operation. It appears very likely that a smelter will be established to handle these ores at Sault Ste. Marie, Ont., since it was shown at the Victoria Mines plant that they could be reduced, and under proper conditions, at a profit. Should the results of concentration by the oil process now under way at the Massey Station mine prove as successful as appears likely, it will bring many of these idle low grade prospects into the market.

The production of nickel (with combined copper) progresses with greater results than ever. Not only has the largest company more than doubled its capacity, but the other two concerns are making preparations for a resumption of mining and smelting in the immediate future. Ontario no longer nearly equals the output of nickel in other countries—it leads the world, and by a large margin.

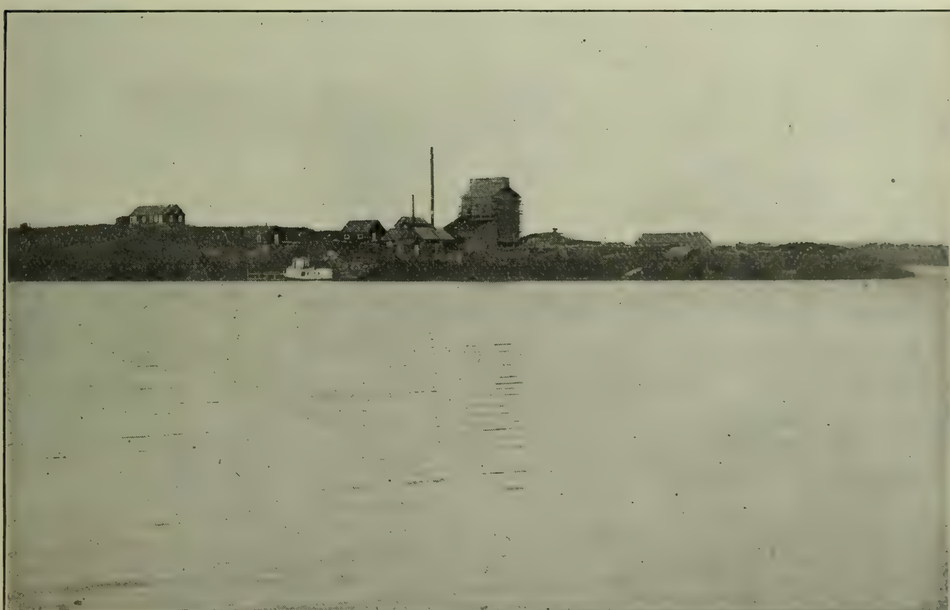
By the finding of the extraordinarily rich silver-cobalt ores in the Temiskaming district last year, one more proof of the possibilities of the Province has been given. In this region also important iron, iron pyrites and arsenic deposits have been discovered, some of which have been under development for a considerable period.

As a result of this general activity in a power-consuming industry, in the Sudbury and adjoining areas, four water falls have been or are being harnessed for the generation of electric energy, purchasable by anyone. This coming year will probably see greater substantial activity in mining centres in Ontario than ever before, which cannot but have its effect in bringing prosperity to all other associated enterprises.

GOLD MINES

Bully Boy Mine

From Mr. Chas. Brent, of Rat Portage, it was learned that during September, 1904, the mining plant consisting of boiler, hoist and pumps, etc., intended for the Nino mine, and which has lain at Whitefish rapids for some time, was purchased and



The Damascus Gold Mining Co., Limited, Shoal Lake, bird's eye view.

removed to the Bully Boy mine, Camp bay, Lake of the Woods, where it will be set up and mining re-commenced, it is hoped shortly. Descriptions of this mine have appeared in Reports of the Bureau of Mines, Vol. VIII, pp. 60-61, 276; Vol. IX, p. 51; Vol. X, p. 73.

Ash rapids, connecting Shoal lake with Lake of the Woods; showing obstruction to navigation when water is low.

Golden Horn mine, showing mill buildings.

Cameron Island Mine

The 10-stamp mill, referred to in the last Report as under erection is about completed. Mining is to be resumed in the spring of 1905, according to a director's report. The company is now known as the Damascus Gold Mining Company, the president being Mr. Joseph Fowler, of Buffalo, N. Y.

Golden Horn Mine

During the past year and to the date of inspection, 2nd October, 1904, mining development dropped off in part, while a stamp mill was being erected. The shaft remains the same depth, namely 255 feet. The first level west drift is now connected with the old shaft, affording good ventilation to that part of the mine. The second level remains unchanged. Third level; the crosscut south at 16 feet in the west drift, was continued to 285 feet, and although it has struck an auriferous quartz vein in the face, there still remains about 50 feet to go, it is estimated, before encountering the first vein outcropping in this direction on the surface.

The shaft house has been raised to 37 feet to the sheave, to allow of dumping into cars on an elevated trestle road, running across to the stamp mill bins. This new mill building lies about 40 feet east of the shaft house and measures 22 by 62 feet plan, by 46 feet high, and contains two one-stamp Merrall's mill batteries, plates, and a Wilfley table, a 6 by 7½-inch jaw crusher, and the other usual accessories. Milling was to commence immediately of the ore dumps and what ore could be stoped out from the first level up.

A proper thawing and preparation house has been erected for the dynamite.

The management remains unchanged. The employees number fourteen, shortly to be increased to twenty.

Sultana Mine

The perseverance of the few men who have latterly furnished the money for the continued exploration of this pioneer mine has been rewarded by the location of more pay ore, on which the mill has been running most of the year. Since last inspection about a year ago the underground work has been as follows: main shaft, 560 feet deep, or 15 feet below the eighth level, with timbering complete to the eighth.

First level: the 40-foot crosscut N. E. from 130 feet S. of main shaft, which connected with an air shaft in No. 2 vein (E. of the No. 1 or the main vein), is now driving N. along No. 2 vein from this air shaft and is 34 feet in length to date, following a narrow band of quartz. From this point a drift was run at a former period to the S., 250 feet in length, but only local pockets of ore were met with.

Second level, north drift: at 12 feet N. a short drift has been started E. to intersect the No. 2 vein at 60 or 70 feet and the Galena vein at about 200 feet; but this work is postponed until a future time. South drift: at 500 feet S., in the long drift through country rock connecting the big stope with the Crown Reef vein, which drift cut away to the E. of the main or No. 1 vein, a crosscut has been driven W. 98 feet, intersecting No. 1 vein at 37 feet in. On this drifts run N. only 10 feet on account of the mixed quality of the ore, but S. 75 feet, and in the latter the ore is being stoped out. The stope measured 30 feet length by 40 feet high, by 8 feet average width.

Fourth level, south drift: at 500 feet S., underneath the corresponding crosscut in the second level, a crosscut has been run W. 98 feet, intersecting No. 1 vein at 62 feet. Drifts on the vein extend to the S. 10 feet and the N. 71 feet on a narrow band of quartz, the ore shoot pitching to the N. and not yet having been reached. At 750 feet S. on the main level another cross drift W. 80 feet took out some ore in an intersecting vein called the Fissure vein.

Seventh level: at 30 feet in the north drift a winze has been sunk to the eighth level, and a little ore stoped out.

Eighth level: this runs N. 30 feet, then E. 34 feet, and again N. 21 feet, and at end of the E. 34 feet turn connects with the seventh level winze, enlarging into a small stope. Near the face of level another winze goes down to 50 feet deeper, all on No. 1 vein. It appears from this new development, that after passing a disturbed area beneath the fault at the seventh level the vein comes in again without having suffered an appreciable displacement. The reason that not much ore has yet been reached in these new lower workings, (seventh and eighth levels) is put down to the fact that all the ore shoots dip to the N. Further development in this direction will, it is thought, strike a continuance of the pay ore. There is also reason for believing that the unexplored portion of the vein from the big stope south may produce additional ore shoots.

The surface and mining and milling plants are unchanged. Mr. J. Johnson is superintendent, employing twenty-one men.

Combined Mine

No visit was made to this property since all mining was suspended in February, 1904. S. Pinchin, the superintendent, informed me that a force of fifteen men were rebuilding the two-mile railroad from the lake to the mine, after the completion of which a six-drill air compressor was to be installed, and mining resumed. At the last inspection the workings measured as follows: Incline shaft 101 feet deep flattening from 22° dip N. to nearly level, and then dipping more steeply again. Size of shaft is 7 by 9 feet. A level was made at 75 feet depth with a N. E. drift 166 feet and a little stoping done therein. From here and the shaft dump 37 tons of ore were milled in July, producing gold to the amount of $10.50 per ton, according to the superintendent. A 40-foot steamboat has been purchased for the use of the company.

Baden-Powell

As outlined in the last Report, the former main open trench on the vein has been made the site of the main shaft. This has been timbered solidly through the cut and waste rock filled in around it. This shaft is now 98 feet deep, 6 feet by 9 feet in size, and inclining 67° W. A level was made at 60 feet depth with drifts N. 17 feet and S. 50 feet. Hoisting is done by bucket on skids and a duplex cylinder single drum hoist engine and 20 h. p. boiler in an adjoining shed. Ventilation is provided by a wooden box or pipe and steam injector.

A 5-stamp mill nears completion on the N. side of the island some 400 feet N. of the shaft, the ore to be trammed across. The mill consists of the usual plant of gravity stamps, plates, feeder and 7 by 10-inch jaw crusher, with the power furnished by a 40-h.p. return tubular boiler, and a 25-h.p. horizontal engine.

A new dwelling house has been erected on the west side of the island beside the office. The owners and management remain the same, the force numbering twelve at date of inspection, 5th October, 1904. Some instructions were given for the completion of the shaft timbering, and for the safe handling of the dynamite.

Pioneer Island

The property by this name comprises a small island mining location McA 245, and lies about one-third of a mile N. E. of the Grace mine, and one-half mile N. W. of the Golden Eagle. The owners are the Northern Light Mining Company, but shortly the property will be transferred to the subsidiary Pioneer Island Mining Company, Buffalo, N. Y. Mr. N. Higbee is superintendent with at present a force of but five. Some work was done a few years ago, and now since the resumption of operations this sum-

mer, a new small camp has been built, and the ore pit 20 feet deep squared out for timbering and continued sinking. The workings are on the south end of the island.

The vein deposit fills a contact between granite on the east and green trap on the west, and consists mainly of iron pyrites and quartz, the former in great abundance and massive. The gossan weathered surface portion is said to pan gold. A very small percentage of chalcopyrite may also be seen. The vein is traceable from the shore inland probably 400 feet, having widths at the few openings varying from one to five feet. The water lot between this and the mainland and an adjoining location thereon are to be included in the holdings of the new company.

Grace Mine

Sinking continued in the main shaft to a depth of 55 feet, reached about the first of the year, when all mining was suspended. This means that but 27 feet of sinking has been accomplished as the result of another year's work. The lower or new portion of the shaft was partly filled with water, but no new developments in connection with the ore body were apparent. The shaft was being timbered into two compartments preparatory to resuming mining. The other workings remain as before. At the foot of the hill, close to the lake shore, foundations have been prepared for a power house and plant. The employees numbered four. A new engine has been fitted into the company's launch.

Eldorado

A new corporation, the Eldorado Mining Company, incorporated under Ontario laws, has taken over this property from the former owners, the Northern Light Mining Company. The president is Walter D. Green, secretary, W. A. Barnhart, and superintendent, N. Higbee. Mining recommenced in June 1904, after a period of inactivity, the force now numbering eight. A description of the auriferous quartz vein appears in the last Report of the Bureau, and also an account of the development to that date. The shaft is now 95 feet deep, and timbered with a ladder-way and skid road for the bucket. The level at 70 feet depth runs S. W. 53 feet. An open head frame covers the shaft, and from this the hoist rope continues 100 feet or so away to the new hoisting plant beside the small 2-stamp mill. This plant comprises a 25-h. p. boiler and a hoist engine.

The first level drift is to continue along the vein S. W. for about 150 feet to meet an intersecting vein at that point which strikes N. 18° E.

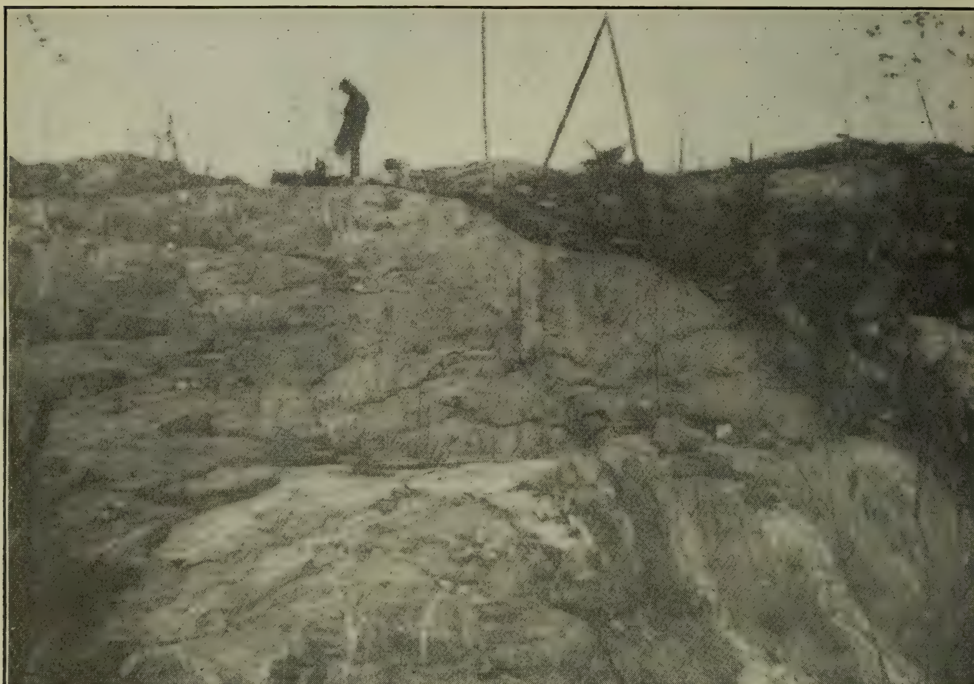
No milling was done this year, but it was the intention to start on this ore in a few weeks' time.

Redeemer Mine

Operations during the past year have been active, but were mainly confined to the surface, in the erection of a stamp mill. The management is in the same hands, with a force increased to twenty. The shaft has been sunk to a depth of 235 feet, but with no lateral work whatever, which makes the present erection of treatment works somewhat premature. Hoisting is still done by bucket. This should be replaced by a safer means, such as a skip or cage, with the depth the shaft has now reached. The timbering of the new portion of the shaft has yet to be completed, and instructions to this effect were given.

The mill is situated 80 feet N.W. of the shaft, and contains 10 stamps, with all accessory plant except vanners, supplied by the Jenckes Machine Co. To tram the ore over, the shaft house has been raised to a height of 36 feet, boarded in and a level trestle road constructed to the mill.

A proper powder-thawing house has been built in a suitable place. A dry-room for the men has yet to be put up. An office has been added to the camp. Milling will commence as soon as the plant is completed this fall.



Redeemer gold mine, vein 75 feet east of shaft.

Redeemer gold mine, shaft buildings and stamp mill.

Ideal Mine

The shaft has this summer been continued down to a depth of 89 feet vertical; it is 7 by 10 feet in size, and timbered with a collar only. But at the date of inspection mining had again ceased, and the small force of four was constructing roads to outlying points for development. The delay is due, according to the superintendent, A. J. Herrington, to lack of cash. All mining has been done by hand, no machinery having yet been acquired. Instructions were necessary for the completion of the timbering in the shaft, and care and safe thawing of the dynamite.

Gold Coin Mine

This is a new property in the Dryden area, and comprises the south half of the north half of lot 6, concession 1, Van Horne township, half a mile from the boat landing, and on the Government road recently constructed to these properties, and due north of the Redeemer mine a short distance. The owners are the Gold Coin Mining Company. Mining commenced in April 1904, and the shaft has since been sunk 55 feet vertical and 7 by 10 feet in size, all by hand work. No one was there at the time of my visit in October 1904, operations having been suspended.

The vein is of quartz, striking east and west with vertical dip through a country rock of greenstone, in which it lies as a lenticular deposit with defined walls. It varies from 14 inches to 4 or 5 feet in width, and contains a small amount of copper and iron pyrites.

Queen Alexandra

The following information respecting this new property was obtained from T. James, the contractor for the mining done. No inspection was made, as the mine had just suspended operations. The location, H W 270, adjoins the King Edward near Carlton and Trout lakes, a short distance west of Lower Manitou lake. A shaft was sunk 85 feet deep, vertical, and 6 by 10 feet in size, on a quartz vein. Machinery consisting of a boiler and hoist, are on hand, but have not yet been set up. A 2-unit Tremaine steam stamp mill was erected and some 18 tons of the ore treated, producing $16.00 per ton in gold. This work was done between February and September, 1904 There is also a small camp of several buildings and a steamboat. F. Bolton was superintendent and representative of the English syndicate which has control of the property.

On the adjoining King Edward locations no further work has been done during the year.

Twentieth Century

All work closed here in November 1903, and in February 1904, the entire plant was dismantled and taken up the lake to the company's new properties, the Laurentian and Volcanic Reef mines, where it is being again erected. The sawmill was, however, left to cut lumber for the fresh ventures. From the superintendent, Dryden Smith the following measurements of the underground work done since my last inspection of a year ago were obtained: shaft, 389 feet deep (49 feet increase). First and second levels unchanged.

Third level: the stope in the west drift was carried up to the second level about 10 feet wide by 55 feet long.

Fourth level: west drift 19 feet wide with crosscuts from the face S. 73 feet and N. 85 feet. At 63 feet in the N. crosscut No. 2 vein was struck and followed to the W. 22 feet.

Laurentian Mine

This new property was inspected on 9th October 1904. It comprises mining location H. P. 371, of 52 acres area, situated about half a mile by a new road west of Gold Rock P. O. The owners are the Laurentian Mining Company, 43 Tremont St., Boston, Mass., and Toronto, Ont., incorporated under the laws of Ontario. The president is Anthony Blum, secretary, John Molath, and mine superintendent, Dryden Smith. The force of miners and surface men numbers twenty-one. This company owns other locations in the vicinity, which are H W 248, 252, 255, 256 and 257.

Operations commenced in October 1903, and since then there has been erected a power house, dynamite magazine, oil shed, machine and blacksmith shop, assay office, dry house, cook camp, sleeping camp, office, three separate dwellings and stables. Building operations are not quite complete on all of these. Foundations for a stamp-mill have also been put down, and all the mining and milling plant (20 stamps) from the Twentieth Century mine has been transported hither. It is to be hoped the several veins will develop into merchantable bodies of ore.

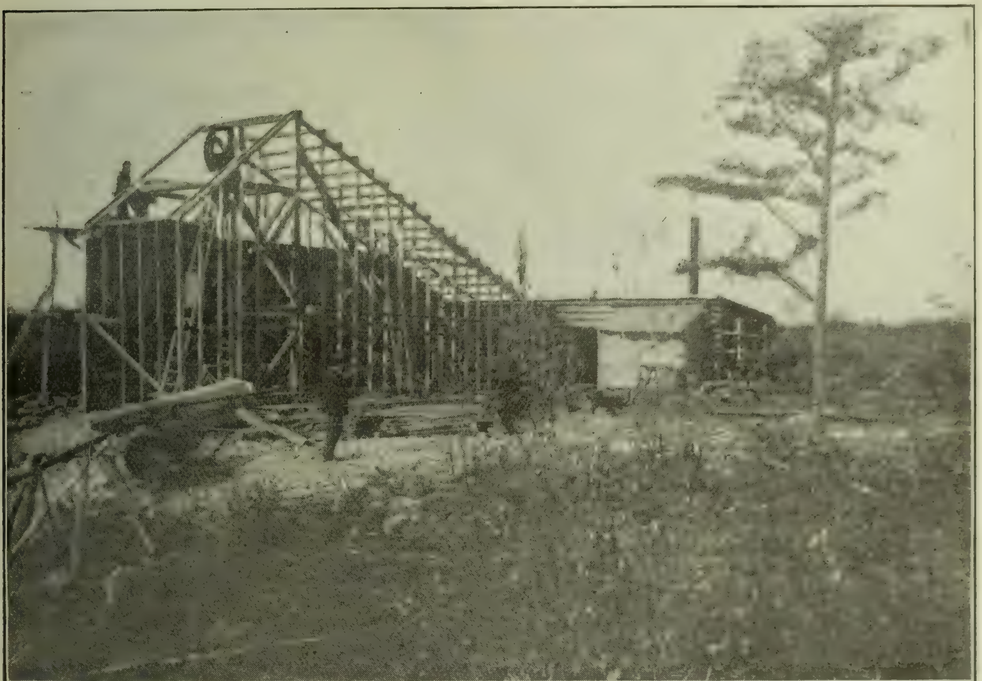
The one shaft has reached depth of 220 feet, inclining about 80° E., and is 7 by 11 feet in size. The only level is at 80 feet depth, with drifts N. 18 feet and S. 43 feet. From the face of N. drift a crosscut runs E. 22 feet; and at 7 feet in the S. drift, another, 17 feet W. for a pump station. In addition to this, the surface of the veins has been stripped at several places. The shaft has a collar and temporary head frame, but no timbers below this, and no ladders below the level. Instructions were given to put the shaft in safe condition by complying with the Mines Act regulations, and to prohibit riding in the bucket. Hoisting was done by a temporarily placed boiler and hoist engine and bucket in skids. Other instructions were necessary for the care and safe handling of the explosives.

The sinking has followed a small vein of dark quartz, which in places produced some showy free gold specimens. On the surface two other veins run parallel to this at 15 feet and 18 feet east of the shaft, and still two more at 50 feet and 150 feet west of it. The first two or three near the shaft may be found to connect, but the others appear as quite distinct deposits. They are all more or less lenticular in character, and lie in and with the strike of the greenstone country rock, which is N. E.-S. W.

Volcanic Reef

This property is operated by the same management as the Laurentian mine, namely, by Mr. Dryden Smith, with a force of fifteen men, and the owners are the Volcanic Reef Mining Company, Boston, Mass., and Toronto, Ont. President, Anthony Blum, and secretary, John Molath. The mining location under development is S 40 but the company also owns H P 377, S 39 and S 41 in the same neighborhood, namely at Mud lake, just east of the upper end of Upper Manitou lake. A mile and a half wagon road has been constructed by the company from the Laurentian to this mine as a continuation of that from Gold Rock. S 40 adjoins the Little Master property, one of the veins (No. 1) on which continues through and forms that which is here under development. It is of quartz, lying in and with the trap formation, and therefore lenticular, and a foot or so in width. From the outcrops on the top of the hill, 168 feet above Mud lake, and 600 feet northerly therefrom, or the same distance northeast of the Little Master workings, the shaft is being sunk, 130 feet deep to date, 8th October 1904, vertical, and 6 by 9 feet in size. A level has been made at 100 feet depth, with drifts N. 19 feet and S. 23 feet. Timbering has kept pace with the sinking, with the expectation of installing a cage shortly. At present hoisting is done with bucket, and a small hoist operated by compressed air, brought by 3-inch pipe from the power house on the lake shore, 1,400 feet distant. The machinery at this latter plant consists of a 50-h.p. tubular boiler and a 3-drill Rand

air compressor. At the mine a new shaft-house will shortly be completed to replace the present temporary arrangements. For the camp two large log houses have been built, and a stable. Some carelessness existed in the care and thawing of the dynamite, for the remedying of which instructions were given.



Volcanic Reef gold mine, shaft and buildings.

Giant Mine

The point of operations has again been shifted, but this time back to the original place on H. W. 75. The shaft and other development work on H. W. 185 is reported to have not given sufficient pay rock to warrant further expenditure. The mining plant has in part been transported over to the lake shore below the old tunnel, and set up with a one-stamp Nissen mill, with which some small test runs on the ore were made. The other camp is still in use however. In June 1904, sinking was resumed in the old 18-foot shaft under and past which the tunnel was driven during 1901-02 to a length of 100 feet. The shaft has just broken through into the tunnel at a depth of 60 feet on its incline of 80° N. W., and intersects the latter at 55 feet in. The vein fills the shaft, 6 feet wide, having defined walls, and being composed of quartz, calcite and chlorite, with a fairly high percentage of iron pyrites.

The stamp mill is connected with these workings by about 250 feet of surface tram road, the plant consisting of a 1-stamp battery, the 18-h.p. mine boiler, engine, feeder, crusher and plates.

P. Paulson remains in charge with a force of six.

Little Master

Development has continued steadily since last inspection under the same management, and with a force of twenty-five men. The main or No. 3 shaft is now 175 feet deep, and timbered most of the way.

First level, 152 feet deep; west crosscut, 175 feet; east crosscut, 130 feet, with a drift S. 20 feet at 105 feet in. A No. 3 Cameron pump unwaters from this level. Hoisting is still done by bucket, but this is operated from a new power house 60 feet S. E. of the shaft. Herein have been installed a new 2-drill Rand air-compressor, the same hoist and another 65-h.p. locomotive boiler. This last was in a very unsafe condition, necessitating instructions for its abandonment. A large new boarding house is about completed, the lumber for which is cut on the premises in a sawmill owned by the company.

The plan of development entails crosscutting from the underground levels to the four more or less parallel veins additional to the one (No. 2 vein) that No. 3 shaft is sunk in. The No. 1 vein lies about 200 feet N. W. of No. 3 shaft, and forms in its N. E. extension the Volcanic Reef mine vein. Shafts Nos. 3 (main) and 2 are sunk in the same No. 2 vein about 300 feet apart. Veins Nos. 3, 4 and 5 lie to the S. E. of the main shaft, all within about 200 feet distance and nearly equally spaced.

Paymaster Mine

This newly opened prospect comprises mining location H W 20 of 83 acres area, and adjoins the Big Master locations to the southeast. It is owned by the Northern Development Company, president, J. E. Burns, and secretary, E. D. Soudan, with offices at 107 Majestic Building, Detroit, Mich. Operations commenced in the fall of 1903 with R. J. Elliott as superintendent. A vertical shaft has been sunk 100 feet deep with a drift N. W. 20 feet from the bottom. Hoisting is done by bucket and small hoist, and a 25-h. p. boiler in an adjoining hoist house.

A couple of neat camp buildings have also been erected.

The shaft started down on one of two lenticular quartz veins about 30 feet apart, each from 18 inches to 2 feet wide where exposed on the surface, and dipping a few degrees to the S. E. with strike about N. E.-S. W. The country rock is the green schist of this district. Work had just ceased at the time of my inspection, 7th October, 1904, but has since been resumed, according to report.

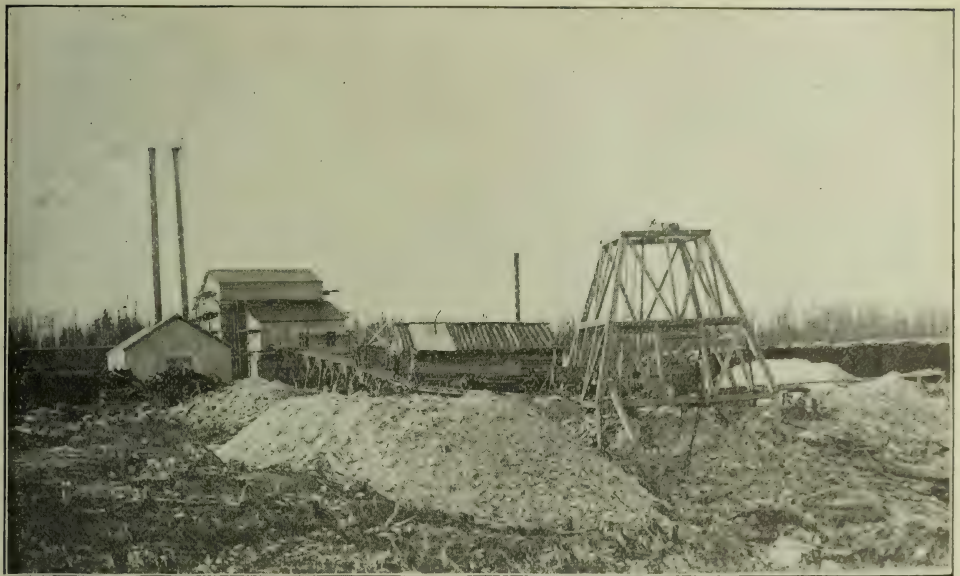
Big Master

Owing to financial difficulties this mine has lain idle since the first of the year. The bondholders recently foreclosed on the former owners, the Interstate Consolidated Mineral Company, bid in the property, and formed themselves into the Big Master Mining Company, licensed to operate under the laws of Ontario, with president Benj. Hammond. The offices of the new concern are at Fishkill-on-Hudson, N. Y., and Gold Rock, Ont. W. Shovells is still in charge, and with a few men has commenced renovating camps and machinery, and strengthening the head frame structure over the shaft with the intention of shortly resuming mining. Additional mining plant in the way of pumps, air drills and hoist may be installed.

According to the office plans the ore shoot in the west vein has been found to widen and lengthen respectively from 2½ feet by 30 feet on the surface to 8 feet by 156 feet on the second or 185-foot level, and 9 feet width in the winze below this point, and to have shown an average value of $17 per ton. The East vein or shoot, so far only opened out along the first or 85 foot level, has a length there of 140 feet, and a width of 12 feet, with an averge assay value of $8.35 per ton.

St. Anthony Reef

On account of the lateness of the season and because practically no mining had been done since the last inspection of this property in 1902, no visit was made on this trip. But later from Mr. J. S. Steele, manager, it was learnt that mining was resumed towards the end of the year, No. 1 open cut being deepened to water level



St. Anthony Reef Gold Mining Company, Sturgeon lake, showing mill building and head gear of No. 2 shaft.

View from Dawson's Cottage (English River Gold Mining Company), looking west.

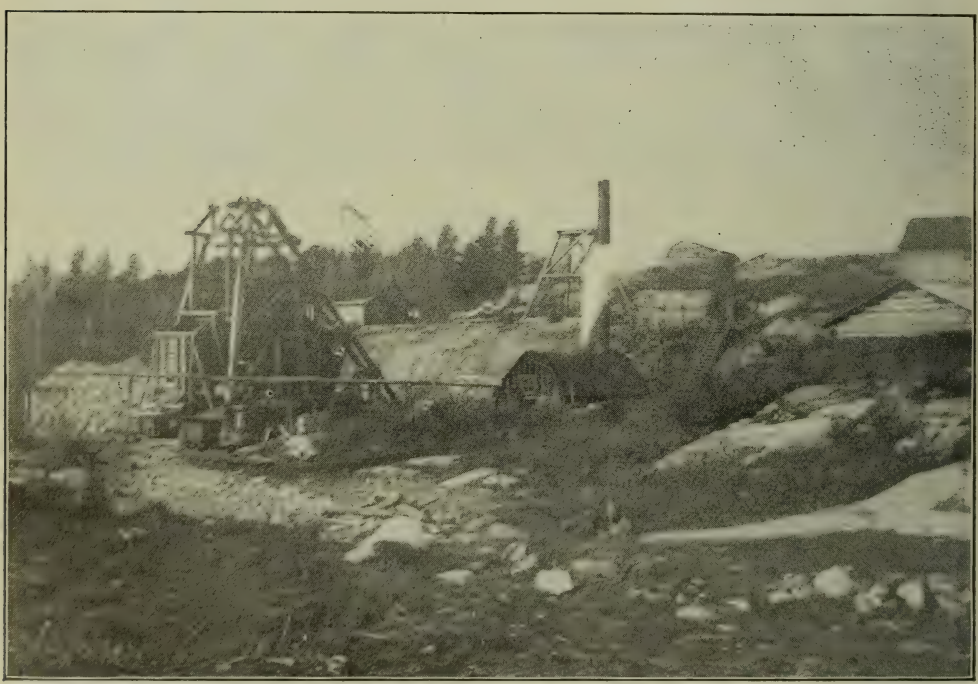
(lake level), that is to 44 feet deep at the breast, and Nos. 1 and 2 shafts being connected by a drift on the underground level. Stoping had begun at this latter place.

During the past year, also, a 10-stamp mill was taken in and erected, a sawmill to furnish the lumber necessary, and a complete mining plant of boiler, hoist, air-compressor, drills and pumps. It was expected that the mill was then in operation, as sufficient ore for some months to come already lies at the dumps.

The employees number twenty.

Sunbeam Mine

This is the old A L 282 property. The owners and management remain the same, but the force of men has increased to forty on account of the enlarged scale of operations. Some additional mining locations have been acquired adjoining or in the vicinity of A L 282, as follows: H P 623 to 626, and X277-8-9, 590-1 and 614. A 10-stamp mill has been built on X614 about three-fourths of a mile distant from the



A. L. 282 or Sunbeam gold mine.

mine on A L 282, and the two connected by a surface tram road operated with horse cars. The milling plant includes 10 stamps of 1,050 lbs. weight, plates, 9 by 15-inch jaw crusher, a 40-h.p. horizontal engine, and in an adjoining building a 40-h.p. boiler. The pump is stationed on the lake shore 200 feet distant. Treatment of the ore commenced in July 1904, and has continued steadily to this date of inspection, 13th October 1904.

At the mine considerable work has been accomplished. The upper 76-foot vertical portion of the shaft has been abandoned and the incline continued straight to the surface for the better operation of the skip. The new shaft head gear combines small ore bins and chutes, from which the tram cars are loaded for the mill. The shaft has reached a depth of 410 feet on the 43° incline N.

First level, S. W. drift, 135 feet (30 feet increase) with a stope 65 feet long by 25 feet high by 6 feet wide.

Second level: in the N. E. drift there are two stopes, one 30 feet long by 8 feet high by 6 feet wide, and the other 35 feet long by 12 feet high by 6 feet wide; S. W. drift, also two stopes, one 30 feet long by 12 feet high by 6 feet wide, and the other 50 feet long by 15 feet high by 6 feet wide.

Third level: in the S. W. drift is one stope 25 feet long by 6 feet high by 6 feet wide.

Shakespeare gold mine; shaft, tunnel and power house.

All mining is done by hand drills. Ventilation depends on the natural air circulation, which will soon have to be aided, if the working places are extended. A new hoist house has been built on the flat beside the boiler house, and contains a new 25-h. p. hoist engine.

A L 200

A short account of this property was given in the last Report of the Bureau on pages 71 and 72. According to one of the officers of the company a little more mining has been done since, consisting of stripping the vein and crosscutting it at about 1,000 feet N. E. of the shaft. Two log camp dwellings have also been built, and it is hoped to recommence development actively this fall.

Shakespeare Mine

Three inspections were made of this mine during the summer of 1904, the second one occasioned by a serious fatal accident whereby six miners lost their lives. A report on this fatality appears in another part of this volume. All operations were

suspended for a month or so after the accident, but since that time have continued steadily since the inspection of last year.

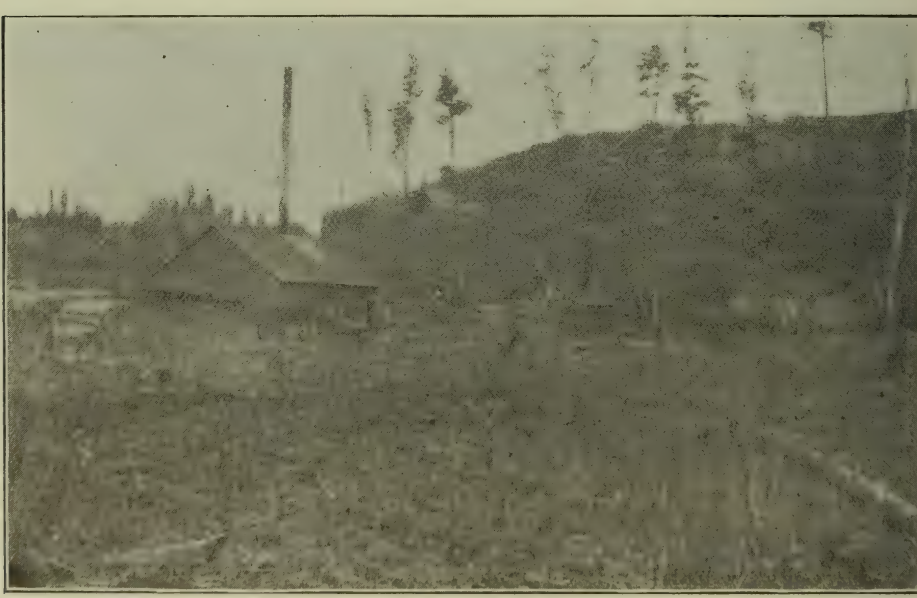
The tunnel reached a length of 75 feet crosscutting the formation northwesterly. At 65 feet drifts were run 43 feet S. W., and 37 feet N. E., with in the latter a crosscut from the face 17 feet S. W. At its face the tunnel connects with shaft at a point 53 feet down. The shaft is in all 95 feet deep, with at 90 feet depth a crosscut S. E. 38 feet. It is timbered into a bucket-way and ladder-way. At the mouth of the tunnel stands the power-house, with 40-h. p. boiler, 3-drill Ingersoll air-compressor and hoist engine. The blacksmith shop adjoins.

From the shaft house a surface tram road runs 200 feet across the ridge to a box chute dumping on to the crusher floor of a new stamp mill now under erection at the foot of the cliff on the flat in the N. side. The plant contains 5 gravity stamps, Frue vanner, plates, 7 by 10-inch jaw crusher and feeder, and a 35-h. p. boiler and 10 by 12-inch horizontal engine, and it is expected will be in operation in a month or less.

At the date of the last inspection, 27th October 1904, Mr. James McKenzie was superintendent, with a force of eight.

Avon Mine

The property by this name is controlled by a syndicate composed of J. C. Foley and associates, and comprises an area of 360 acres in Shakespeare township adjoining the Shakespeare mine, made up as follows: N. half lot 4, concession I; S. half of lot 4, concession II; and the S. E. quarter of S. half of lot 5, concession II. Mr. J. C.



Avon mine, compressor plant. Tunnel in hill to right.

Foley is in charge, with a force of fourteen men. The present mining work is exploratory, consisting of surface cuts, and the tunnel 200 feet long to date, driven S. E. across the same rock ridge or hill in which the Shakespeare workings lie, and at about one-quarter of a mile farther N. E. A compressor plant has been erected near the tunnel, containing a 50-h. p. boiler and a 3-drill Rand air-compressor. The camp buildings number three.

Instructions were given for greater care in storing, handling and thawing the dynamite.

Lucinda Mine

This property consists of the N. half of section 11 and the S. half of section 2, Fenwick township, situated near Goulais bay, lake Superior, and is reached by road or trail from Searchmont, Algoma Central railway, some 35 miles north of Sault Ste. Marie. A shaft has been sunk 65 feet deep and in addition some surface stripping has been done. A 45-ton Huntingdon mill was installed this summer, but after a few days run all operations were suspended.

The property is owned by the Lucinda Gold Mining Company, Sault Ste. Marie Mich., secretary, Chas. M. Dysinger, and president, F. M. Dale.

IRON MINES

Williams Mine

Considerable activity has marked the development of this property since the last inspection of a year ago. At 30th October, 1904, the shaft had reached a depth of 200 feet, and was carefully timbered and divided into two compartments, for ladder-way in one and bucket-way with guides and cross head in the other. A level has been opened at 200 feet depth with drifts S. E. 20 feet and N. W. 74 feet at 30 feet. In the latter a crosscut runs N. E. 42 feet; and at 35 feet in, another S. W. 86 feet. All drilling is done by hand. A new blacksmith and carpenter shop had just been completed, the old one to be converted into a dry room. Ventilation is provided for by a 12-inch pipe with steam jet suspended down the shaft and along the level to the working faces. From February to May 1904, 1,500 feet of diamond drilling was done, the five holes being all bored from the bottom of the shaft, serving to guide the subsequent development outlined above. One hole inclined 70° northeasterly, passed through 16 feet of clean hematite at 322 feet depth. With the opening of the level a body or vein of clean, solid ore was struck 4 feet six inches in width, and this extends through the drifts. Nothing further was met in the N. E. crosscut, but in the S. W. one a series of ore bodies was cut through about as follows, and in addition to the body in the main level: from the drift S. W., 16 feet slate, 2 feet mixed ore 4 feet clean ore, 3 feet mixd ore, 7 feet clean ore, 9 feet slate, 7 feet mixed ore, 8 feet clean ore, 30 feet to face in black schist. The aggregate width of clean ore is 19 feet, and of lean ore 12 feet.

With the stoping out of some of these bodies shipments will, it is expected, be made during the winter, and for the purpose a wagon road is to be constructed around the N. E. shore of Loon lake, about two miles in all, to connect with the Algoma Central railway at Wilde station. Mr. C. C. Williams is manager, and employs a force of eighteen men.

Helen Mine

With the removal of the financial difficulties of the Lake Superior Corporation in the spring of 1904, this mine resumed operations, and has since been producing and shipping at the rate of about 1,000 tons of ore a day. Mr. R. W. Seelye is superintendent, and employs a force of between 150 and 160 men. The largest portion of the output of the mine is going to the United States, filling contracts made previous to the erection by the company at Sault Ste. Marie of its own blast furnaces. A fair amount has however already been stocked at the blast furnace dock at the Soo. It brings a high price in foreign competition on account of its value as a mixer with the prevailing soft ores of the States.

No more ore is now raised from the open pit, but all is milled to the underground levels and hoisted out by way of the shafts. There are two of these 100 feet apart. No. 1 is used for development purposes, and No. 2 for hoisting ore, and both are about 200 feet deep. The pit floor, 90 feet below the surface, counts as the first level; the second is at 168 feet depth. On this, drifts run approximately at right angles to one another, undermining the ore body, and from suitable points raises have been made to the pit floor 80 feet above, down which the ore is underhand stoped or milled from the pit to the second level, to form large stock piles. From these the desired quantities can be trammed to produce the best grade mixture of ore. These mill holes have been so located that each produces one of the several distinct grades of ore. According to Mr. Seelye, the first grade is hard compact red hematite, 60 per cent. iron and over; the second porous but hard brown limonite, 57 to 58 per cent. iron; the third, soft brown limonite, 53 to 54 per cent. iron. The grades low in iron are on the other hand freer from phosphorus and sulphur, so that by judicious mixing an ore of the following average content can be maintained:

	Per Cent.
Iron	61.40
Silica	4.50
Phosphorus	.087
Sulphur	.085
Water	3.75

When shipping, the skips dump the ore direct into the rock crusher at the top of shaft house, whence it drops into the 50-ton ore cars to be hauled at once to the ore docks in Michipicoten Harbor. In winter the ore will be stocked underground, and not on ore piles in the open as formerly. No. 2 shaft is now sinking to open out a third level to repeat the operations on the second.

The surface plant has been partially remodelled by lowering the shaft house and crusher some 36 feet, and installing a new large double drum hoist and the two air compressors (14- and 6-drill respectively) in a new power house on the bared banks of Boyer lake now pumped out. A new battery of four boilers in the same building supplies power for the entire workings. The rest of the plant remains the same as before.

Instructions were given for certain changes in the place and method of thawing the dynamite, and also for greater safety in its general care.

Preparations have been made for hydraulicking and pumping out the mud which overlies the 60-foot deposit of iron pyrites to a thickness of 30 to 35 feet in the bed of Boyer lake. This mud will have to be removed before the pyrites can be handled.

COPPER MINES

Massey Station Mine

Inspections were made of this mine twice in 1904, one in June and the other in October. On the last occasion a change had been made in the staff, Mr. H. W Hardinge being superintendent, and Mr. Barclay having resigned from treasurership of the company. The mine had been closed temporarily in July, during the construction of the oil concentrator, but had again opened at the time of my second visit. The number of employees has been increased to forty-four.

The shaft had not been sunk any deeper.

First level: unchanged.

Second level: small overhand stopes in both E. and W. drifts.

Third level: E. drift, 54 feet with overhand stope to the face 32 feet high, and ending in a raise to the second level, and connecting by winze with the fourth level.

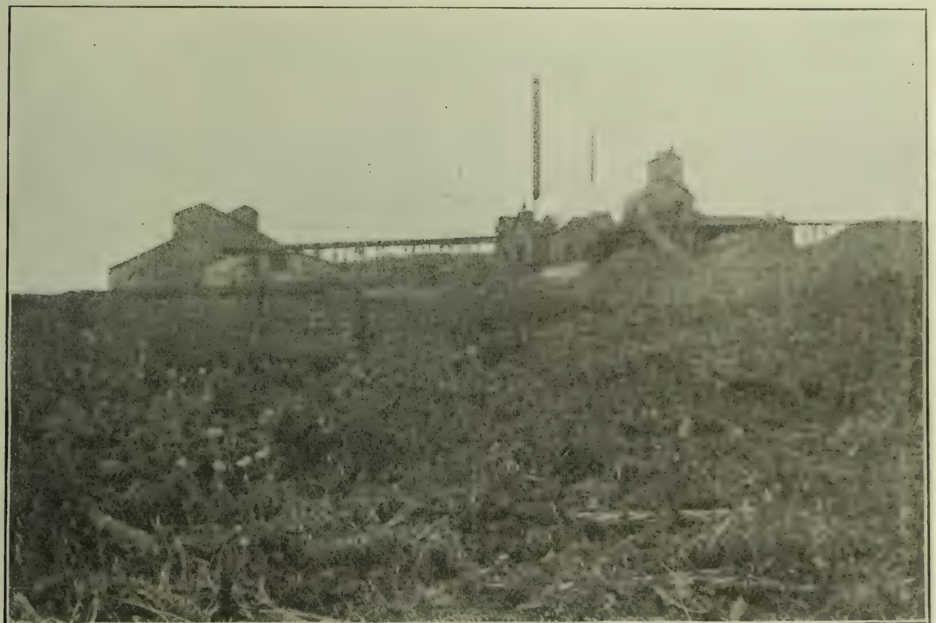
Fourth level: E. drift 140 feet with a crosscut from the face S. 30 feet, and a stope 64 feet long by 20 feet high; W. drift 243 feet, with at 141 feet in a crosscut S. 16 feet, and a stope 55 feet long by 55 feet high, terminating in the raise to the third level.

Fifth level: E. drift 52 feet, and W. drift 30 feet.

Sixth level: E. drift 17 feet, and W. drift 35 feet.

Seventh level: E. drift 115 feet, with at 50 feet in a crosscut N. 50 feet; W. drift 37 feet, with at the face crosscuts N. W. 85 feet and S. 15 feet.

The shaft partition has been put in to the fourth level, according to subsequent advice from the manager.



Massey Station copper mine, oil concentrator and mine looking west.

The rails were laid on the side line of railway from Massey station this spring, and the machinery and plant for the new concentrator brought in. By October the plant was completed and in operation.

The accompanying illustrations will give an idea of the size of the building. The ore treatment consists of first wet concentration on a Wilfley table of the fairly coarse pulp, and subsequent separation of the chalcopyrite out of the finely pulped remainder by taking advantage of the affinity of this mineral for oil. The plant consists of a Krupp ball mill, a Wilfley concentrator, a tube mill and a 2-unit (50-ton) Elmore oil plant. The engine operating the whole is supplied with steam from the adjacent mine boiler battery. The first runs with the plant are giving good results.

Hermina Mine

Development has progressed actively at this property during the past year, with at present a force of 15 to 20 men. It was inspected on three occasions during 1904 to see that several instructions regarding its safe operation were carried out. The last visit was made on 28th October 1904. Mining has during the year been confined practically to one place at the southeast end of the property, by sinking a shaft 202

feet deep, vertical, and 7 by 10 feet in size, with the first level at 90 feet depth, on which a crosscut runs E. 25 feet, then turning S. 40 feet, and a second level station just being opened. The timbering for a bucket-way with crosshead and guides, and a ladder-way was being completed to the bottom. The shaft follows down a vein of almost clean chalcopyrite from one to two feet wide, which lies in a green trap.

A solid head frame has been erected over the shaft, and a short distance away a power house containing the mining plant of a 50-h. p. boiler, 6-drill Ingersoll air-compressor, duplex cylinder, 3-foot drum hoist engine and pumps. The blacksmith shop adjoins, but the same camp is in use about three-fourths of a mile to the west, where a new office has been built.

The wide vein at the N. W. end of the lots received some further attention by sinking a 10-foot pit out of the surface crosscut mentioned in last year's report.

A satisfactory dynamite thawing-house has been added, and another separated shed is to be used immediately for storing the oil.

Eagle Copper Mine

A short account of this mine was given in the Twelfth Report of the Bureau, page 101, under the heading Goulais Bay. In addition to the S. W. quarter of section 14, the company also control the N. W. quarter of section 14, the S. W. and N. W. quarters of section 23, and the S. E. quarter of the S. E. quarter of section 15, all in Vankoughnet township, aggregating 600 acres.

Most of the mining has been done on the S. W. quarter of section 14, consisting of a shaft 55 feet deep, vertical, and 6 by 11 feet in size, with, at the bottom, a crosscut running S. 37 feet, and then E. 66 feet. At 40 feet in this last 60 feet another crosscut was driven S. 18 feet. At 200 feet S. E. of the shaft a tunnel enters the hill for 90 feet in a S. E. direction. The vein is composed of quartz carrying chalcopyrite and galena, with values in gold and silver. A mining plant has been installed consisting of a 14-h.p. boiler, pump, a steam drill and a hoist engine. The camp is made up of two dwelling houses.

The above information was obtained in October, 1904, from Mr. A. G. Terrill, who contracted for the mining done, no inspection being made because of the suspension of operations a few days previous.

Superior Mine

This property suspended development a few days before my arrival in the district, and no inspection was therefore made; but from Mr. F. M. Perry, manager, it is learned that all work has during the year been confined to No. 6 shaft, which has reached a depth of 260 feet, with the first level at 100 feet depth and drifting thereon N. W. 25 feet and S. E. 25 feet; and the second level at 200 feet depth, with drifts N. W. 25 feet and S. E. 25 feet. The surface plant remains unchanged. The reason given for the stoppage is that the mine has reached the point where it is advisable to prosecute development on a larger scale with increased mining plant and facilities of transportation, such as a side line of railway from the Algoma Central railway, and also where some means of treating the ore must be decided on. It is a question either of concentrating at the mine or shipping the ore to Sault Ste. Marie to be smelted at a customs plant, which may be erected there, or possibly of both. As soon as the future plan of operations is decided on the owners intimate their intention of resuming work.

WHISKEY LAKE COPPER AREA

The Whiskey Lake area, so-called from the presence within its boundaries of a fairly large lake of that name, is included at the present time within four townships, each six miles square, and known as Nos. 137, 138, 143 and 144. These are contiguous in the form of a square, whose southern boundary lies two townships north of Sheddon

and Lewis, which border on the north shore of Lake Huron. The lower end of Whiskey lake is distant about fifteen miles due north of Cutler, on the Canadian Pacific railway, Sault Branch, from where one may reach the lake by canoe, up the Serpent river waters. Lumbering operations, however, practically close this river for navigation until the fall of the year. The usual route followed is by a roundabout road 33 miles long from Massey Station, farther east, northwesterly through the townships of Salter and Tennyson, and township No. 130 to the east side of Whiskey lake, after which all travel is by canoe through the lakes and rivers which abound in the region. Another road of about the same length, but in a worse condition for travel, goes northeast from Spragge, to the west of Cutler, arriving at Picard's lake. At this point the canoe is taken, passing up Whiskey creek, about three miles in length, and thence into Whiskey lake.

Most of the townships in this district have been under timber license to lumbering firms for thirty years or more, with authority to cut the pine and other trees thereon, and the existence of these valuable timber interests has operated to discourage pros-

H. E. Long's quartz-copper vein; outcropping on west side Corner Lake, Timber Berths 137 and 143.

pecting or mining, which would tend to expose the timber to danger of loss by fire. Most of the townships have been cut over once, a number of years ago, but the timber then too small to take has grown in size, and in certain portions of the limits is now merchantable. Where the lands have been denuded of their timber this obstacle to mining does not, of course, exist.

The occurrence of copper in the area has been known for a number of years, but not until recently have other than the original one or two finds been made. These new deposits have proved to be unusually continuous, as a result of which the locators have taken up considerable areas of land, some of which have been surveyed, and the rest simply applied for, pending the opening of the district for mining. The excellent specimens of ore sent out also gave the appearance of worth to the discoveries, warranting the present short examination of the field.

The district has several characteristic features in which it differs from the lower land to the south, amongst these being the large number of lakes, long and narrow for the most part, separated by high rocky hills and connected one with the other by typical mountain streams. Although the hills do not rise much over 300 feet from the lakes at the foot, they are unusually precipitous and strewn with rock debris. The rocky nature of the country is frequently hidden at a distance by the heavy growth of stout, healthy trees of both hard and soft woods.

For a couple of miles or so north of Massey Station the road passes over quartzites intersected at intervals by dikes of greenstone, probably diorite, and then into a stretch six to ten miles wide composed entirely, as far as could be observed, of the igneous rocks, granite gneiss and diorite, the last intersecting the other in narrow or, more frequently, extensive eruptions. At Whiskey lake the quartzite again appears, and here, as in the belt to the south, it is broken up by a series of more or less parallel intrusions of diorite, having a course east and west and vertical dip. Where observed, the width ranges from 100 feet to as much as half-a-mile. In texture the diorite is usually medium-grained, granular and green in color, although along its contacts with the quartzite this disappears in an alteration towards a darker compact schist.

The quartzite, in texture, composition and color, varies considerably, but in the main is of rusty white, clear quartz of medium grain. From this it ranges through a pinkish arkose with the feldspar in fair abundance towards a fine-grained grayish rock also felspathic; and on the other hand towards a quite coarse rock, almost entirely quartz in composition, having somewhat the appearance of a conglomerate from the presence of embedded stones measuring as much as six or eight inches across. These large inclusions are, however, composed of practically identical material.

Along the east shore of Whiskey lake, where also the eastern boundary line of the townships in this area runs, granite outcroppings appear on some of the hills, but whether they are of intrusive origin as well as the diorite, or merely outliers from the Laurentian rocks to the north, was not determined, no copper veins having yet been discovered on that side of the lake and area.

An examination of the different mining locations shows three distinct classes of veins or ore deposits, according to their characteristics, but all appear traceable in the first instance to faulting or fracturing, subsequent to the solidification of the greenstone ejections.

Campbell's Island

On Campbell's island, near the centre of Whiskey lake, and at the falls at the head of the lake one and the same class of vein occurs. It consists of lenticular quartz fillings in blocky green schist, the quartz carrying galena and iron and copper pyrites in irregular pockets, which are quite small and unimportant in value where exposed by the few open cuts and strippings. A sample from one of these openings on the vein at each location gave by assay only traces in gold, but from $1.00 to over $3.00 per ton silver, according to the quantity of galena present. The amount of copper was too small to need a determination.

Campbell's island has an area of about 160 acres and rises very steeply to a height of 185 feet above the lake. It consists of a mass of diorite, and through the face of a bluff of this on the south side, at 125 feet above the lake, the quartz vein outcrops, striking about N. W.-S. E., with a dip of thirty degrees N. E. The vein can be traced for about 225 feet in all, having a width of four or five feet for 75 feet N. W. of the one opening, but pinching out to narrow stringers in the remaining 150 feet in the opposite direction.

The other location referred to as at the head of Whiskey lake, takes in, as applied for, the land on both sides of the 100-yard stream and falls (20-feet drop) which empties Bear lake into Whiskey lake. The lenticular quartz vein lies on the east side of the stream and was traced back east from the water's edge 300 or 400 feet, with widths of two to six feet. The strike is east and west and dip about vertical.

This class of vein lies well within the interior of the greenstone bands, and has no apparent connection with the contact disturbances to which are due the most important class of ore body described hereafter.

The Peyton Location

The class to which the second variety of vein belongs is yet doubtful. It will probably be found to have lenticular characteristics. Only one example is so far known, and that on mining location W R 94, called the Peyton location, on the west side of Whiskey lake and southwest of Campbell's island. The vein outcrops at the shore, mostly under the water, and cannot be traced for more than 100 feet altogether. Apparently it pinches out inland, as nothing is to be seen of it in the rock bluffs back of the shore. It lies in the quartzite with vertical dip, and a strike N. 70° W. well within one of a series of bands of this formation alternating in a N. and S. direction with other bands of greenstone.

Quartz and chalcopyrite compose the vein and ore. Of this from the exposure on the shore a small amount was raised by open pit which ran high in copper content. In a 25-foot shaft sunk a short distance back from the lake the quartz body breaks up into a few smaller stringers with less copper. The small amount of work done, with the meagre surface exposure is insufficient to give any idea as to the continuity of either the vein or the copper values therein.

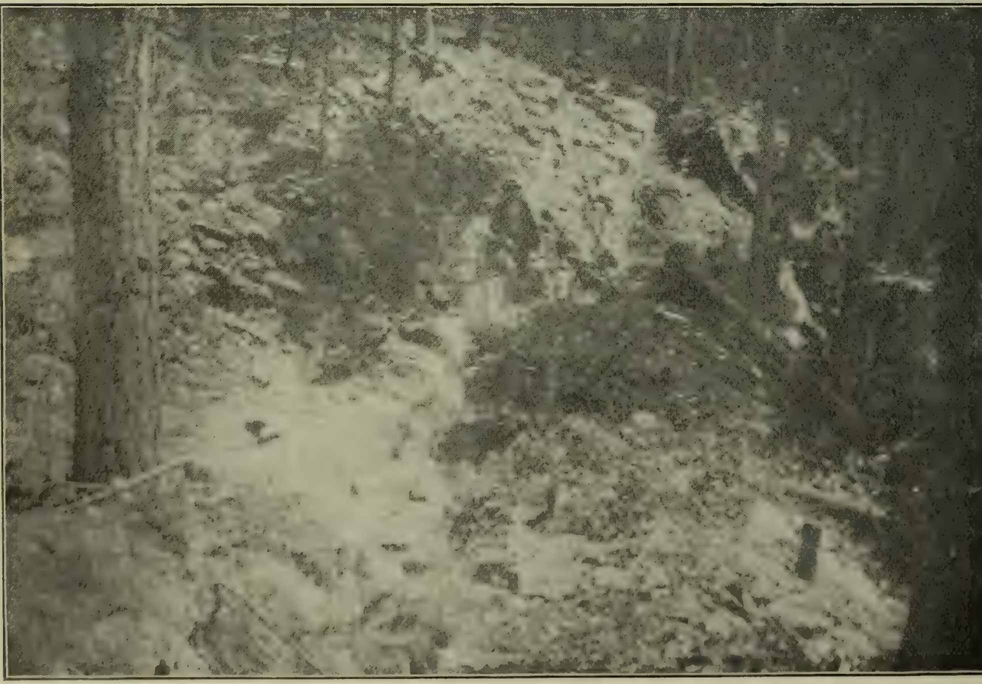
The veins of the third or remaining class have been found more frequently than either of the others, and from their unusual continuity along unvarying lines of strike, and the generous distribution of fair to merchantable quantities of copper at all points where uncovered, they undoubtedly form the most important deposits of copper ore in the area. They constitute fillings of quartz and chalcopyrite along faulted or merely shattered zones of the greenstone, always either in or quite close to its contact with the quartzite. The greenstone or diorite side of these contacts evidently marked the main lines of weakness in the rocks of the area, since no other disturbance approaches the prominence of this.

Where a clean fault was made the vein has all the characteristics of a true fissure deposit. The walls are often slickensided and lined with more or less gouge, being in such case well defined. Most of the gangue consists of quartz, especially where the vein has narrowed down, the only other rock being trap, which is interbanded through the quartz in greatest quantity where the vein is widest. The brecciated ore bodies, which follow lines or zones of fracture rather than of faulting in the diorite, are composed mainly of the trap itself in angular masses, both large and small, cemented together with a much smaller quantity of quartz and chalcopyrite. The walls in this case are rather indefinite; the ore will probably be found to quickly decrease in copper content as the undisturbed rock on either side is approached.

The strike of these copper veins, like that of the contacts of the diorite and quartzite they follow, is most often a few (about ten) degrees south of west, but it varies locally as much as 45 degrees. The veins have a width of three or four feet to over twenty feet. The copper occurs as chalcopyrite, and constitutes practically the only sulphide present, iron pyrites being visible in the gangue and the walls alone. The chalcopyrite is both finely disseminated and in large masses or bands, sometimes a foot wide. As very little work has been done it was not possible to fairly sample the veins for their copper content; but it will be neither too much nor too little to say that they are very good prospects.

THE LONG TOM LOCATIONS

H. E. Long's quartz-copper vein, stripped on north side McCool lake, Timber Berth, 137.



H. E. Long's quartz-copper vein stripped on W. R. 91, Timber Berth 137.

One of these veins is especially interesting. It was discovered and located by Mr. H. E. Long, who has since traced it for nearly three miles, and for a further distance of two or three miles more on either side he found similar outcroppings of apparently the same deposit. The locations covering it have since been surveyed and filed with the following numbers, from east to west, W. R. 118, 114, 113, 119, 91, 115, 116, all in the northwest corner of timber berth 137, and W. R. 116, 117 and 126, adjoining in timber berth 143. For about half their total length these locations border on and include most of the land under the waters of McCool and Corner lakes. The property is now known as the Long Tom, and aggregates about 1,760 acres. H. E. Long and Jas. J. McFadden are the two applicants. The vein lies along the contact between diorite on the south and quartzite on the north, but entirely in the diorite, and has been uncovered and trenched at numerous points along and near the north shore of McCool lake, and at the prominent outcrops on both sides of Corner lake. The fissure now filled by this vein follows an almost straight course S. 80° W.

The Reynolds Property

The Reynolds property consists of mining location W R 92 at the northwest end of Whiskey lake and between it and Bear lake and the short stream which joins the two. It lies in timber berth 138, about a mile north of the east end of the Long Tom locations. Chas. C. Reynolds is the locator, and jointly with some associates, the applicant. The outcroppings and what work has been done on them in the way of a big open cut, are reached by a short trail from the bay on the Whiskey lake side about 300 feet north of the creek mouth. The vein has the same strike as the Long Tom, namely S. 80° W., with about vertical dip and at the one opening is twenty feet wide. This width seems to be maintained in the 300 feet over which it was traced under the moss. It is composed of quartz and the slightly altered hornblende country rock, closely intermixed into a dark mass, through all of which chalcopyrite is disseminated in considerable porportion, mainly in a fine state. In this case the contact of the enclosing greenstone with the quartzite lies to the south a short distance, nearer the shores of Bear lake.

The other deposits do not need any special description. One is covered by mining location W R 93, and from its position at the easterly end of the Long Tom properties may be a continuation of that vein. It is on another small lake on the east and west line dividing timber berths 137 and 138.

Another copper-bearing lode of this class was discovered a few days prior to my visit, and has been applied for as mining location Y 352, by J. A. Montague and associates. It borders on the west shore of Whitefish lake, which is about one-quarter mile west of the lower stretch of Whiskey lake, into which it empties by a swift mountain stream. It is reached by way of Whiskey lake, by a trail starting from the camp of the first vein mentioned, W R 94. The vein cuts across a mountain or high hill, which rises several hundred feet above Whitefish lake, the first exposure being 235 feet up. It lies in or near the contact btween the greenstone on the northeast and the quartzite on the southwest, striking approximately N. W.-S. E. The vein consists of a coarsely fractured zone of the trap cemented with quartz, with the chalcopyrite mostly in the latter. The few uncoverings show a width of about ten feet of vein material. Some stripping and other surface work was done on it during the summer.

A year or so previous to my visit to this area some similar copper veins were discovered and superficially explored farther south, probably half way between the Massey Station copper mine and these Whiskey lake deposits, and reached by the same road from Massey Station. This may indicate a considerably larger copper-bearing area than has so far been defined.

NICKEL-COPPER MINES

With the resumption of ore reduction in the new smelter plant of the Canadian Copper Company, the reopening of the Mond Nickel Company's mines and smelter at Victoria Mines, the exploration by diamond drills of the Lake Superior Corporation's nickel mines prior to a resumption of development, and the opening up of some smaller but new nickel prospects, the outlook for the coming year is very bright in the Sudbury nickel camps. Depending on the capacity of the market to absorb the product, the output of the high-grade matte should be much greater in 1905 than ever before. The Mond Nickel Company's nickel refinery in Wales has just been enlarged to double its former capacity, so that there need be no cause for another suspension of production at their Canadian mines and works for lack of an outlet for the matte.

The nickel ores of the Province have been added to by the new finds of cobalt-nickel arsenides and silver near Haileybury in the Temiskaming district, although for a time the probability is that these ores will be treated out of the Province.

Visits of inspection were made to these mines in June and October, 1904.

The mines of this area, nickel, copper and any others, will shortly have within reach all the electric energy they can consume. Besides the development of the High Falls water power for use by the Canadian Copper Company's mines and works, three other water power companies will shortly have electric energy for sale.

Power house of the Sudbury Power Company, McPherson falls, Vermilion river, Creighton township.

One is on the Wahnapitae river about three miles south of Wahnapitae station, C. P. R., where the head of water is 53 feet, the maximum power 5,000-h.p., and the amount to be used or developed 2,500-h.p. Another is at McPherson's falls, on the Vermilion river, on lots 11, concessions I and II, Creighton township, about ten miles due south of Larchwood, C. P. R. main line, and about sixteen miles west of Sudbury. The head of water here is 25 feet and the capacity of the power 3,000

h. p., of which about 1,200-h. p. is to be now made available. The Sudbury Power Company is undertaking this work. In addition to these two which are simply for the sale of electric power, there is another source of a limited supply at the Spanish River Pulp and Paper Company's pulp mill near Espanola, where a drop of 60 feet on the Spanish river is now under control for the development of 10,000-h. p., and at some future date, as desired, of the total capacity of 22,000-h. p.

CANADIAN COPPER COMPANY

Two set-backs were encountered by this company during the year by the burning down first of the Ontario Smelting Works in February, and in June of the West smelter. By leasing the plant of the Mond Nickel Company at Victoria Mines the problem of refining the low grade matte product of the West smelter was overcome. But with the destruction of this latter plant all production work had to cease until October, when the new smelter commenced operations.

The management has been active in incorporating the most modern economic ideas and practices into all parts of the works, and many changes and improvements are noticeable over the conditions of a year ago. New plant is bought from time to time, such as locomotives and other rolling stock, roadbeds improved, new lines laid out, and new buildings erected at different points to increase the capacity or efficiency of the various parts of the operations at mines, roast yards, machine shops, foundry and so on, not forgetting the beautifying of the town of Copper Cliff by an occasional coat of paint.

The only changes in the staff are the appointment of P. R. Bradley to the position of smelter superintendent, and the resignation of Mr. Baird, and of Mr. R. Taylor as smelter foreman. In June the employees numbered 1,082. This is somewhat reduced now with the completion of the smelter plant.

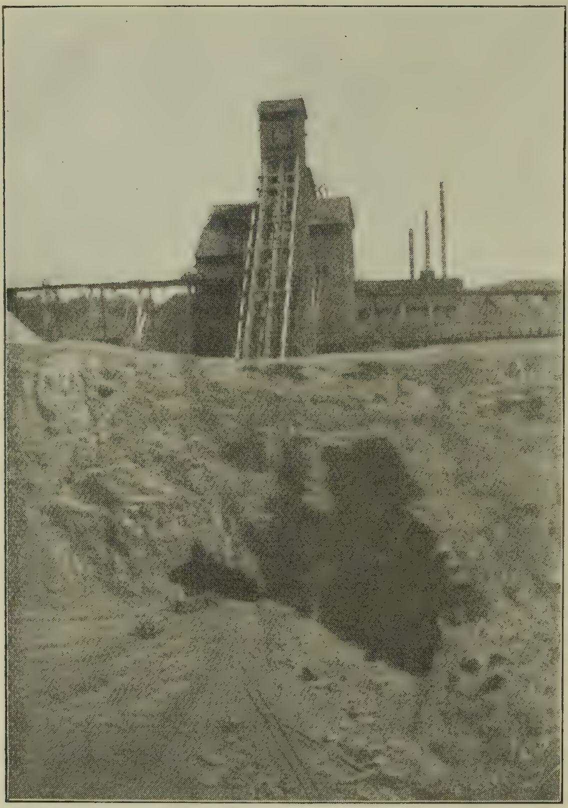
After several preliminary trials the new smelter began its continuous run about the end of October, 1904, for the production in one operation of high grade Bessemer matte. The last Report of the Bureau contains a general description of this plant; in detail the different parts are as follows: Two blast furnaces, capacity 550 tons of charge each per day; three Bessemer converters in place, revolved electrically; four settling wells; slag pots on double truck cars; electric travelling crane to handle converters and matte pots; in the power house, a battery of four water-tube boilers with water purifying system; condenser plant; three blower engines, one for the converters and two for the blast furnaces; two electric generators of 250 k. w., each connected to high speed Corliss valve engines; two lighting dynamos of 75 k. w., belt driven by high speed Peerless engines; and many pumps and other accessory machines.

There are no important changes in the roast yards. No. 3 contains about 100 heaps of various sizes, and No. 1 about 65, comprising about 175,000 tons of ore, about all the company care to have lying idle preparatory to smelting, since half this is sufficient to insure a steady smelter supply. For this reason not many heaps have been built latterly.

Creighton Mine

Mr. Geo. A. Sprecher was in charge of this mine, with a force of 177 men in June and 100 in October. The pit now measures 250 feet by 300 feet plan, by the same depth of 60 feet. The shaft has been extended down to the second level, 140 feet deep, with double skip road and ladder-way; a drift runs from the bottom S. 70 feet, and a raise from there to the pit floor, down which the ore is now in part stoped. This latter working place has a diameter of 50 feet, and forms a pocket for storing large quantities of ore ready for hoisting. The output from the pit and second level has averaged about 500 tons a day, with a maximum of nearly 1,000 tons a day. The surface is being stripped to the S. and S. E., preparatory to the extension of the pit in that direction.

The mining plant is the same except that a new double drum five-ton hoist has replaced the former one. A fine manager's dwelling has been built in addition to several other dwellings for the employees.



Creighton nickel mine, looking south.

This is the only mine belonging to the company which is now producing nickel ore, all the remaining working ones having been closed during the summer and allowed to fill with water. The Creighton has such immense reserves of high-grade, cheaply mined ore that it will be unnecessary to operate the other properties, probably for many years to come.

Copper Cliff Mine

Towards the last the output of this mine amounted to only 80 tons of ore a day, which though unusually rich did not compensate, the company state, for the expenses entailed in the operation of such a deep mine, and in August 1904, the pumps and other machinery were raised, and the mine permitted to fill with water.

The last new work consisted in re-opening the bottom of the old big stope on the thirteenth level, and breaking down considerable ore from the sides and far face. Nothing worth while now remains there. After stoping out all the ore about the winze from the thirteenth to the fourteenth levels to a size of 10 feet width by 40 feet length, the same winze and then the stope were continued down about 75 feet deeper, the stope here being somewhat wider, but of the same length. The continued nickel-copper content of this ore ranged from ten to twelve per cent., mainly copper.

Vermilion and Krean Hill Mines

In January 1904, the Vermilion mine was re-opened by the Canadian Copper Company, who now have the controlling interest. It was originally known as a gold and platinum deposit, and a small stamp mill, now entirely gone, was erected to treat the ore. But after passing through the few feet of weathered surface or gossan, into the unaltered sulphides, no more free precious minerals were found, and so the venture terminated. It has always been known as a remarkably rich nickel deposit, though small and irregular, and the present development is for further exploration only. A small mining plant consisting of a three-drill air-compressor, 60-h.p. boiler, small hoist engine and pump was set up to facilitate the work. The old camp has again been made use of.

The workings comprise several small open cuts and one large one 8 feet wide by 50 feet long E. and W., by 12 feet deep. Out of the centre of this a shaft has been sunk 57 feet deep, vertical, and 7 by 7 feet in size, and from the bottom drifts run S. E. turning E., 80 feet; and W. 60 feet. At 80 feet S. E. of this shaft is another old one, now full of water, but reported to be 60 feet deep. The ore lies in an irregular contact between quartzite or arkose on the S. and S. E. side, and schists and greenstones on the N. and N. W. side, occasionally extending into the latter, in lenticular pockets and stringers more or less connected and continuous, in widths varying quickly from a few inches all the way to eight feet. Two diamond drill holes were bored near the old shaft.

This mine is reached by a two and a half mile road from Victoria Mines. About half way in it branches off to the Krean Hill property about one and one quarter mile farther north, where the company have four miners doing a little prospecting on a deposit of nickel sulphide ore somewhat similar to the Vermilion.

Other mention of these deposits will be found in Reports of the Bureau of Mines, Vol. IV, p. 36; Vol. VII, pp. 142-3; Vol. XII, p. 272.

Huronian Company

The International Nickel Company have formed another subsidiary company under the above name to develop the water power at High falls on the Spanish river, for the purpose of transmitting electric energy to the mines and works of the Canadian Copper Company at Copper Cliff. High falls is situated about four miles north of the Canadian Pacific Railway, Sault Branch, at Nairn, and about twenty-six miles southwesterly from Copper Cliff. Instead of cutting a right of way for the pole line the latter will be put up along the Canadian Pacific railway tracks to Copper Cliff. The river at the falls breaks up into several channels over a dike of greenstone, and necessitates an unusual amount of dam building. Two large dams will confine the stream into the head race, the rocky hills forming the other sides. Four smaller dams will close up other channels and a seventh in the west channel will take the overflow and be provided with a log chute. There will also be a heavy bulkhead at the end of the head race above the power house, from which four nine-foot diameter steel penstocks will descend at an incline of 85 feet in 200. All dam work is to be concrete. The present drop is 67 feet, but when raised by the damming a head of 85 feet will be attained at which it is estimated the total power will be 22,000-h. p. About one-half of this, or 11,000-h.p., will be transformed into electric energy by the present development, and the plant arranged for the utilization of the rest on short notice. A four-mile line of railroad was first of all (in the spring of 1904) constructed from the Canadian Pacific railway tracks at the new station Turbine in to the falls.

Messrs. Ross & Holgate, engineers, have charge of the work, and Mr. Geo. Revell is resident engineer. The force of workers number 300, for whom a large number of dwellings have been erected. It is expected the power will be ready for use by the end of 1905.

VICTORIA MINE

During the year since last inspection the mine remained closed. A few days prior to my visit of 26th October 1904, unwatering was commenced, the intention being to

resume ore raising as soon as possible and fill the roast yard so that by spring smelting might again begin. The smelter plant has not been idle long, however, being used under lease from February to July by the Canadian Copper Company, for raising their low grade matte to a high grade product, and also for a short time making smelter tests in the Massey Station mine copper ore. No changes of importance have been made in the plant.

Mr. H. W. Hixon has returned to take charge again, and informs me that Dr. Mond's nickel refining works in Wales have just been doubled in capacity. This will allow of immediate treatment of all matte the Victoria plant can turn out.

The Mond Nickel Company has continued mining at the North Star, which mine was under lease to it, and has had all the ore shipped to the Victoria smelter yards, where it is stocked to the amount of about 15,000 tons. It is to be smelted now.

North Star Mine

Inspections were made of this mine in June and October 1904, and it was found still working under lease to the Mond Nickel Company, with Mr. C. V. Corless in charge, and a force of from forty to forty-eight. An average of 100 tons of ore is raised per day, and immediately shipped by rail to the Victoria mine smelter. The above lease has until December to run. The open pit or trench on the ore body has been deepened to 175 feet by means of a shaft down its centre for the first 100 feet and between pillars for the remaining 75 feet. From the bottom of the shaft short drifts through these pillars lead into the stopes on either side. The E. stope extends 80 feet from the shaft and up to the surface 10 feet to 15 feet wide; and the W stope, 120 feet from the shaft and up to the surface, but higher up not more than 100 feet in length, and from 10 feet to 20 feet wide. Both E. and W. faces have reached the end of the workable ore. To determine whether or not it extends down to greater depths in sufficient widths a number of diamond drill holes are being bored.

EVANS NO. 2 MINE

This nickel prospect had a little surface work done on it a few years ago, and now is undergoing somewhat more extensive development. It consists of the following parts of lot 7, in the third concession of Snider township, aggregating 100 acres: N. W. ¼ of S. E. ¼; N. E. ¼ of S. W. ¼; S. W. ¼ of N. E. ¼; and the S. E. and S. W. quarters of N. W. ¼. The Manitoulin and North Shore railway cuts across the N. W. corner of the lot, at 8¼ miles west of Sudbury, and three-quarters of a mile east of the North Star mine. J. W. Evans of Deseronto, Ont., is owner, and J. A. Baycroft, superintendent. The employees number four. This last work commenced in August 1904, when a small camp was erected. A shaft has since been sunk 23 feet deep, with a five foot crosscut at the bottom on a small but fairly well defined zone of mixed ore in gabbro.

IRON PYRITES AND ARSENIC

Steep Rock Lake

During the exploration with diamond drill and otherwise for iron ore in the vicinity of Steep Rock lake, Western Ontario, by Messrs. Mackenzie, Mann and Company, a valuable vein of iron pyrites was discovered. This happened towards the end of 1903, and further work on it extended into 1904, but no ore raising has yet been undertaken. The locations on which it lies are A L 460 and 461 on the west side of the west arm of Steep Rock lake, and adjoining these A L 472-3-4 and 462 have also been acquired. Five diamond drill holes were sunk within a distance of 1,200 feet, showing that below the badly weathered and indeterminable surface

indications an almost clean vein of iron pyrites exists, having widths from south to north (its direction of strike) of 6, 9, 13, 21 and upwards of 12 feet. The pyrites was sand-like in the last hole, caving in on the drill rods to such an extent that drilling had to be stopped. The widest places held the cleanest ore, although all, according to Mr. J. A. Wood, the superintendent, is of shipping grade.

Development to the productive state has been postponed; and in the meantime explorations of a similar nature are being conducted at other points on the lake for further deposits.

The vein of pyrites appears to follow a fault plane in the light colored chloritic schists of the area, which badly squeezed and alterated portion of the rock it has replaced.

Another party of prospectors was conducting explorations for iron or iron pyrites in the same neighborhood, but had not found anything at the time of my visit, October 1904.

James Lake

Mining locations W S 404 and 405, 109 acres in area, are situated a short distance west of the Temiskaming and Northern Ontario railway, at Rib lake siding, nine miles north of lake Temagami, and bordering on James lake. They are owned by Major R. G. Leckie, Sudbury, and have been under development by him for the past year or so, for a deposit of iron pyrites. A small camp has been erected on the shore of James lake to house the force of five to eight men.

The ore consists of a fairly clean body of pyrrhotite on one side and iron pyrites on the other, across a total width of forty feet, and apparently lies in a contact between hornblende granite on the northwest and green schist on the southeast side with a strike northeast-southwest. So little rock is exposed on account of the uniform covering of soil and moss, that a more complete idea of the general geology of the locations could not readily be obtained. By means of a 24-foot shaft and several pits and open cuts the ore body has been explored for a distance of 400 feet. One complete cross-section, beginning on the southeast side, shows 5 feet of clean pyrites, 6 feet of rock more or less highly mineralized, 12 feet of clean pyrites, and finally about 15 feet of pyrrhotite, which is probably a fair average of the amount of each in the body. The iron pyrites are said to assay from 48 to 50 per cent. sulphur, with traces only of gold. The pyrrhotite is not thought to be of value since it carries only from $1.00 to $2.00 per ton gold, about 0.5 per cent. copper, and from 1 to 1 5 per cent. nickel.

Major Leckie expects to build additional camps and mine houses, increase his force and ship ore during the coming season. The proximity (one-quarter mile) to the railway will allow of very cheap transportation, a necessity to the mining of iron pyrites.

Arsenic Lake

Locations W S 13 and 14 are also owned by Major R. G. Leckie, who has had them under development for a year or more, with a force of about seven miners. They lie on a small pond known as Arsenic lake, which is one and one-half miles by road northwest of mile post 74 on the Temiskaming and Northern Ontario railway two miles north of Temagami. So far tents have sufficed, but a substantial log camp is to be built at once. The ore found here is mispickel—arsenical pyrites—filling a shear zone about 8 feet wide in the green schist of the area. Two solid, clean bands of ore, aggregating three to four feet in width lie on each side of a central lower grade somewhat wider portion, having a strike about south-southwest by north-northeast. The ore will probably be sorted into two grades when mined, on account of its irregular outline and composition, the greatest width of solid ore so far explored being only 3 feet, whereas a safe average of the whole merchantable body is about 8 feet. The clean ore carries, according to assay, $16.63 per ton gold and silver, and

30 per cent arsenic, and the second grade not over 10 per cent arsenic. Copper and iron pyrites are also present, the percentage of copper running from 0.5 to 1.5 per cent. Stripping with open cuts has laid bare a length of 60 feet by a width of 20 feet along the ore body.

The number of arsenic deposits already discovered and opened up in this immediate area may warrant the erection of an arsenic refinery in their midst. On this same road, but much nearer to the railway, lies the Big Dan arsenic locations, found a number of years ago, but only this year explored to any extent.

CORUNDUM

Canada Corundum Company

With the gradual adjustment of the new mill to the ore and mining conditions, the scale of operations has increased at all points. Quarries appear to almost cover a very large portion of the hillside in which the ore occurs, and the mill concentrates now nearly 200 tons of ore a day, with a corresponding output of 10 to 12 tons of

Canada Corundum Company, view of corundum hill.

corundum. Certain modifications, such as curtailment, alteration or increment of various parts of the process and plant have been found advisable in the interest of increased economy and capacity, but other than this the plant and operations remain practically the same as at last inspection. Mr. D. G. Kerr is manager, employing a force of from 135 to 140 men.

A number of new buildings have been erected near the mill, including office and analytical laboratory, and in the flat opposite a small hamlet of workmen's cottages

has sprung up, the old camps being inconveniently distant now that all work is confined to this one locality.

It is expected with this complete system and plant that grain corundum of such purity will be uniformly produced as to insure a steadily increasing demand. There

Canada Corundum Company's mill.

need be no doubt about a constant supply for a long time to come, if not indefinitely, but it requires time for the trade to appreciate this superior but somewhat more expensive abrasive.

Ontario Corundum Company

This company was unfortunate enough last spring to suffer the destruction of its new mill by fire. But with unquenched energy plans were immediately prepared for another and better plant, and at the time of my inspection, 20th September 1904, this was nearing completion. A different process is to be employed, namely, dry concentration throughout. The two main buildings are the boiler house and mill. In the former a 125-h. p. boiler is installed to do all the drying by steam as well as to run the plant. The plant comprises five Blake crushers, one 9 by 15 inches, two 7 by 10 inches, and two 4 by 10 inches; two "lightning" (impact) crushers or pulverizers; two rolls; dividers; magnetic separator—the Noble; seven Hooper pneumatic jigs; a dryer; a 75-h. p. horizontal engine and electric lighting plant. The ore will be dried immediately on arrival from the mine and will remain dry thereafter.

Mining is confined to the same quarry, but from now out sorting will not form so important a part of this work, since most, if not all, of the ore will be concentrated.

A force of twenty men is employed under superintendent W. Mackie.

MINES OF EASTERN ONTARIO

BY E. T. CORKILL

GOLD MINES

The production of gold in eastern Ontario in 1904 amounted practically to nothing, although a number of gold properties were under development. The Belmont mine, which ceased operations in 1903, has not as yet been re-opened. It is very unfortunate that a mine which gave such promise as the Belmont should be allowed to lie idle. Financial men still have faith in the gold mines of this section, since two new mills were erected durng 1904, and additional companies are being formed for the purpose of developing in this district. One thing, however, is to be regretted, and this has been pointed out in former reports, namely, the large sums of money spent on the surface in the erection of stamp mills, and installation of expensive machinery, when little or no development work has been done to prove the extent of the ore body. This cannot be wholly blamed on the managers, as the stockholders think that dividends should begin to come in as soon as work is commenced.

Craig Gold Mine

The Craig property, owned and operated by the Craig Gold Mining and Reduction Company of Newark, N. J., comprises the south half of lots 4 and 5 in the third concession of the township of Tudor. It was first opened some years ago, and in 1896 a shaft was sunk on it to a depth of 100 feet. It was re-opened in 1904, and active mining work begun under the management of W. A. Hungerford.

Two shafts have been sunk at a distance of about 400 feet apart, the south shaft to a depth of 110 feet. At a depth of 60 feet a level has been run, the north drift being 280 feet and the south drift 40 feet in length. Stoping is carried on in both drifts. In the north shaft, which has been sunk to a depth of 110 feet, a drift has been run south a distance of 80 feet from the 60-foot level.

A Rand compressor plant, two 80-h. p. boilers and double drum hoist to hoist from two shafts have been installed. Two shaft houses have been built with ore bins complete, also blacksmith shop, store house, boarding house for 75 men and office. A new mill 80 by 32 feet was erected in 1904, and a Merrall 3-stamp battery, triple discharge, was installed. This is the first mill of this pattern erected in Canada, and a large tonnage is claimed for it. The present capacity is about 17 tons per day.

A force of forty-seven men is employed.

The Pearce property owned by the Cleveland Mining Company was worked for some months in 1904.

The shaft is sunk to a depth of 185 feet. Levels were established at 60 feet and 100 feet, and 320 feet of drifting was done. The air was supplied from the Atlas Arsenic Company's works, which are one mile distant. The mine was not in operation at the time of my visit, but Mr. W. A. Hungerford, manager, supplied me with the above information.

Star of the East Mine

This mine, owned by the Star of the East Gold Mining and Milling Company, is situated on lot 24 in the tenth concession of Barrie township, Frontenac county, and was in operation during the whole of 1904.

There are two veins on this property running parallel, about 60 feet apart, in an easterly and westerly direction. On the south vein three openings have been made, the deepest of which is about 30 feet in depth. On the north vein a shaft 180 feet deep has been sunk. The shaft is 18 feet by 11 feet, solidly cribbed for 25 feet, and timbered the entire depth. The first level is at a depth of 80 feet, from which drifts have been driven 50 feet east and west. No stoping has yet been done. Hoisting is done by means of a bucket operated by a duplex cylinder hoist, 24-inch drum. A boiler of 30-h. p. capacity supplies power to the hoist and to the drill. The mill, which was constructed in 1904, is situated about one-quarter of a mile from the mine. A 10-stamp battery was installed during the past winter, and now handles the output of the mine. The ore is first crushed to one inch and smaller and fed into the stamps where it is reduced so as to pass through a 60-mesh screen. After passing over the plates the pulp passes on to a Wilfley table. The concentrates, which consist chiefly of pyrites and a little magnetic iron, are saved for future treatment. A magazine built of stone with tin roof, boarding house offices, stables and some houses for men have been built.

The veins occur in crystalline limestone from four to six feet in width, dipping about 85 degrees to the south. Lenticular massess of quartz occur in the vein associated with pyrite, magnetite, actinolite, calcite and zincblende (not common). Bismuth and bismuthinite have also been found in the vein. The enriched zone is about three to four feet from the hanging wall.

IRON MINES

Radnor Mine

The Radnor mine, owned by the Canada Iron Furnace Company, was the chief producer in 1904 in the eastern part of the Province. About 2,500 tons of ore was shipped during the winter to the company's furnace at Radnor Forges, Quebec On account of all mining being done from open pits, the difficulties met with during the winter were considerable. As a consequence, only one pit was being worked at the time of my inspection in February, 1905. This pit is called No. 7, and is situated 300 feet northwest of No. 8. These open pits are in a semi-circular form from north to south, beginning at No. 7, which is the most northerly, and following in rotation Nos. 8, 5, 6, 1, 2 and 3. These pits show that the deposit has a uniform pitch of 38 degrees to the southwest. No. 8 pit was worked during 1904, but closed for the winter for reasons mentioned above.

Diamond drilling was carried on by the company in 1904, holes being put down southwest of the openings and the deposit found to be quite uniform with depth.

No. 7 pit now being worked is 40 feet long, 30 feet wide and 15 feet deep. The ore is a coarse-grained magnetite interlaminated with gneiss. Before shipping, it is sorted into two grades: (1) middlings, carrying about 30 per cent. iron; (2) good ore, carrying about 50 per cent. iron.

It has been shown that the low-grade ore could be concentrated by means of magnetic separators. If this method should prove a success commercially, a great amount of ore which at present is worthless could be made marketable.

A force of twenty-five men was employed under superintendent D. J. McCuan.

Mineral Range Iron Company

The properties belonging to the Mineral Range Iron Mining Company, which are described quite fully in the Eleventh Report of the Bureau, were not worked to any extent during the past year. The success of the properties depends on the railway facilities and means of transportation being provided. Mr. H. C. Farnum, the manager

of the company, is now endeavoring to have a railroad built from L'Amable station on the Central Ontario railway to Barry's Bay station on the Canada Atlantic railway. This road, if built, would furnish transportation for both the iron of Hastings county and the corundum of Renfrew county.

The Mineral Range Iron Mining Company have done a great deal of work in stripping and proving their properties, and claim to be able to ship 1,000 tons of ore per day as soon as they are afforded means of outlet. Numerous assays of the ore show the ore to contain from 50 to 60 per cent. iron, from .01 to a trace of sulphur, and a trace of phosphorus.

Experiments have been made upon the ore from the Ledyard iron mine at Belmont with a view to reducing the sulphur contents by magnetic separation. Very satisfactory results were obtained, the sulphur content being lowered to one-tenth of one per cent.

In the vicinity of lake Temagami some diamond drilling was done in 1904 to explore the iron ranges of that district. Owing to difficulties encountered progress was very slow, and but little development was accomplished. It is expected, however, that further work will be done during the coming season.

IRON PYRITES

A greater interest is being taken in the development of the iron pyrites properties of eastern Ontario. The production of this mineral here dates back to the year 1900, when ore was shipped to the Nicholls Chemical Works, to be used in the manufacture of sulphuric acid. Since that time the production has steadily increased, resulting in the discovery and development of new bodies of ore ,and interesting other capital in the development of this industry.

American Madoc Mining Company

The property known as the Jarman Pyrites mine, about one mile southeast of Bannockburn, was worked continuously during 1904. At the time of inspection the employees numbered forty, A. F. Rising being superintendent. The shaft has reached a depth of 190 feet (an increase of 15 feet since last inspection.) The ore has been stoped down to the third level, below which all work is now being carried on. The north drift on the third level, which is at a depth of 175 feet, is 175 feet in length, and the south drift 90 feet. A 10-foot pillar is being left in the floor of the third level north drift, and stoping and sinking is being carried on simultaneously below this level. Dams have been constructed on the third level, in order to catch all the water from the upper workings, and a Cameron sinking pump installed. Hoisting with bucket has recently replaced hoisting with the skip.

Another property situated on lot 23 in the twelfth concession of the township of Hungerford, about one-quarter mile from the C. P. R. and near the village of Bogart, was worked by this company for some months during 1904. The development work has shown up a large body of ore. The vein runs a little north of east and dips to the south.

The depth of the main shaft on the vein is 160 feet. At the 100-foot level the east drift is run 40 feet and the west 35 feet. From the west drift a crosscut has been run north a distance of 100 feet, cutting several veins of pyrites. The two widest veins average 10 feet each of marketable ore.

A complete plant, consisting of air-compressor, boiler, hoist and rock house, is being put in, and preparations are being made for extensive mining operations.

British American Pyrites Company

The British American Pyrites Company, Limited, of Toronto, commenced development work on lot 11 in the eleventh concession of the township of Madoc on the first of October, 1904. A force of nine men is employed under superintendent E. L. Fraleck.

Considerable stripping and crosscutting was done, and a shaft 7 by 12 feet has been sunk to a depth of 60 feet, all in ore. The pyrites is very high grade, some samples running as high as 50 per cent. in sulphur; an average of about 48 per cent. is maintained by sorting out the wall rock. A well defined fahlband is here traceable for a mile. The diorite appears altered on the surface to talc and chlorite schists.

LEAD MINES

Hollandia Mine

The lead mine owned by the Ontario Mining and Smelting Company, and formerly known as the Hollandia lead mine, was actively worked during 1904. A circular water-jacketted blast furnace was installed and two carloads of pig lead produced. Considerable work was done on the surface during the past summer in stripping, proving the vein to outcrop for at least 2,500 feet. All mining work is now being carried on from No. 1 shaft, which is vertical, and has a depth of 100 feet, with drifts run for a distance of 25 feet along the vein from the shaft. Nos. 2 and 3 shafts were also worked during the year and some stoping done. The galena is here found in veins associated with calcite in a dark colored schistose rock which may be called a diorite gneiss. The veins cross the strike of the country rock.

The force consisted of fifteen men under superintendent H. F. E. Gamm. Mr. Gamm has recently been succeeded by Mr. Cushman as manager, with Mr. Ellis as superintendent.

Frontenac Mine

Further work was done on the Frontenac lead mine in 1904. This property is part of lots 15 and 16 in the ninth concession of Loughboro township, and is described in the Geological Survey report, 1866-69. One opening 40 feet deep has been made and about 500 tons of the mixed ore (galena and zincblende) raised. The vein is about 11 feet in width, and maintains its width as far as developed.

A mill test of this ore was made at the Kingston School of Mining, showing a saving of 70 to 80 per cent. of the lead in the ore with coarse crushing. As shown by the report on this test, the ore carries from 5 to 10 per cent. of lead and 2 to 4 per cent. of zinc. The concentration is best done by crushing in rolls, then passing over the jigs to get rid of the tailings. The jig concentrates run over 60 per cent. lead and are high enough in lead for shipment. What goes through the jig screens (12-mesh or under) can be passed over the Wilfley table with a fair separation of the galena, and these two operations will save from 70 to 80 per cent. of the lead in the ore. A greater saving might be made, but it is doubtful whether it would not cost more than it is worth in labor and equipment. The ore contains but very little silver, not more than one or two ounces per ton.

ZINC MINES

The Richardson zinc mine, on which development work has been being done for the last three or four years, has now reached a depth of 109 feet. A new vertical shaft is being sunk at a point 250 feet west of the old shaft. This is now down 65 feet

with 2 to 3 feet of ore in the bottom. A shaft house has been erected and boiler and straight-line air-compressor installed. A concentrating mill is also being built,

Richardson zinc mine, showing concentrating mill.

the machinery consisting of a Sturtevant crusher, rolls, jigs and tables. It is expected that all machinery will be in position by July, 1905.

COPPER MINES

The discovery of copper pyrites in the Coe iron mine near Eldorado station in Hastings county was referred to in the last Report of the Bureau. As soon as discovered the mine was leased under option to the Medina Gold Mining Company, Col. Saunders, president, who were under contract to sink 50 feet on the vein. Work has steadily progressed and the shaft is now down about 50 feet. A crosscut was run at a depth of about 30 feet, showing a good width of vein.

The copper pyrites when first discovered occurred in a vein a few inches in width in the hematite. This vein widened as sinking progressed, developing a lead of considerable width. Copper stain had previously been noticed when the mine was worked for the iron, and a small piece of native copper was found near the surface of the deposit. The ore is high grade, due no doubt to a secondary enrichment from the leaching out of the copper from the overlying gossan.

The Parry Sound Copper Mining Company did a little work at the Wilcox mine during 1904. The work consisted of deepening shaft No. 1 from 135 feet to 145 feet, and then crosscutting 100 feet. The ore averages about 4 per cent. copper.

FELDSPAR MINES

The production of feldspar in Ontario has up to the present been confined exculsively to Frontenac county. Owing to the somewhat limited demand for the mineral, and consequently the difficulty in finding a market, no very large production is likely to be reached. During 1904 work was done on several properties along the Kingston and Pembroke Railway in Bedford, Oso and Portland townships.

No. 2 pit, or northeast part of the Richardson feldspar mine.

The largest producer is the mine owned and operated by the Kingston Feldspar Mining Company in Bedford township, known as the Richardson mine. This mine has been a steady producer since 1900, the spar maintaining its high grade qualities which earned for it its market. An analysis shows it to contain the following:

	Per Cent.
Silica	66.23
Alumina	18.77
Potash	12.09
Soda	3.11

The feldspar is mined from a large open cut and is hoisted to the top of the hill, a distance of 50 feet, in 2-ton buckets. These loaded buckets are conveyed on wagons to pontoons on Thirteen Island lake, on which the ore is loaded. It is then

taken by tug across the lake to a portage, placed on cars and drawn across to Thirty Island lake. From there it is taken by tug and pontoon to a spur of the Kingston and Pembroke Railway at Glendower, where by means of a steam hoist the ore is loaded directly on to the cars, or into a pocket. The company have been at a large expense to complete this system of transportation. Now the spar is not handled by manual labor from the time it is mined until it is delivered on the boats at Kingston.

The quarry is divided into two openings, No. 1 or southwest pit, and No. 2 or northeast pit.

No. 1 is at a depth of 50 feet and has an area of 250 feet long by 50 feet wide. No. 2 is the same depth and is 300 feet long by 30 feet wide.

A ditch was dug in the spring of 1905, 600 feet long and 15 feet deep to drain the pit. Stoping is being carried on from the north end of No. 2 pit, which has a width

Loading skips on pontoons at Thirteen Island lake, Richardson feldspar mine.

of 35 feet by the same depth, and on the south side of No. 1 pit, where a stope 15 feet in height is being begun. By means of two derricks hoisting is being done from both pits by two duplex cylinder hoists. An output of 100 tons per day is now maintained.

A force of thirty men is employed under superintendent M. J. Flynn.

The two pits or open cuts, while coming together on the eastern side, are separated on the western side by a large mass of quartz which intrudes into the feldspar. A very perfect separation of the quartz and feldspar is here seen, the quartz having crystallized out in large masses and overlying the feldspar on the western side of No. 2 pit.

Another mine a short distance from the Richardson on the south half of lot 3 in the third concession of Bedford, owned by Charles Jenkins of Petrolia, was worked

for about six months during the year. A small force of men was employed under foreman Jos Harris. Three pits were being worked at the time of inspection with a production of 25 to 30 tons per day.

Mr. A. M. Chisholm worked a property on lot 5 in the fourth concession of Bedford for a short time during the year. About 300 tons of feldspar were mined during this period.

On lot 10 in the fifth concession of the township of Oso, near Sharbot lake, Messrs. Mills & Cunningham of Kingston did some development work. Considerable stripping was done, and a very good body of ore exposed.

MICA MINES

The mica production in Ontario in 1904 was a great deal less than during the preceding year. This decrease was due to the depression in the electrical business in the United States and consequently a lessened demand for the phlogopite (amber mica). The mica mines of Ontario are becoming every year more under the control of the large electrical companies, who mine simply for their own use and not for the market. On this account, there is a smaller demand for mica on the market, and the production varies with the consumption.

As a result of this policy the General Electric Company, who are the largest producers in Ontario, only operated one of their mines during the last year. Their other mining work consisted wholly of prospecting for new deposits. The Hanlan mine near Perth, which produced a large tonnage in 1903, remained idle during 1904, and the Lacey, probably the largest producer in Canada, was not worked to its full capacity.

Another thing which has without a doubt affected the mica industry is the turning of old dumps, which were thrown out at a time when the grades of mica below five inches square were not marketable. This has furnished a large quantity of very cheap mica of the small sizes. This is more particularly applicable to India and the United States in the white mica trade than to Canada. These dumps have now nearly all been worked over, and as a result the price of mica will almost necessarily increase. Very little new development has taken place lately in the mica trade.

The utilization of the so-called "milky" mica has become a question of interest to some of the companies. This "milky" mica is a steel gray color, while the typical phlogopite is brown to amber. While the physical conditions of these two micas are so different, their optical properties are similar, with the exception of microscopic inclusions symmetrically arranged in the "milky" variety. This "milky" mica can be used, but the cost of cleaning and splitting is greatly increased and the percentage of marketable mica resulting therefrom very small. As pointed out by the writer in a paper read before the Canadian Mining Institute, the change is due to a segregation of titanium by secondary alteration.

A comparison of the analysis of the three varieties of mica is here given:

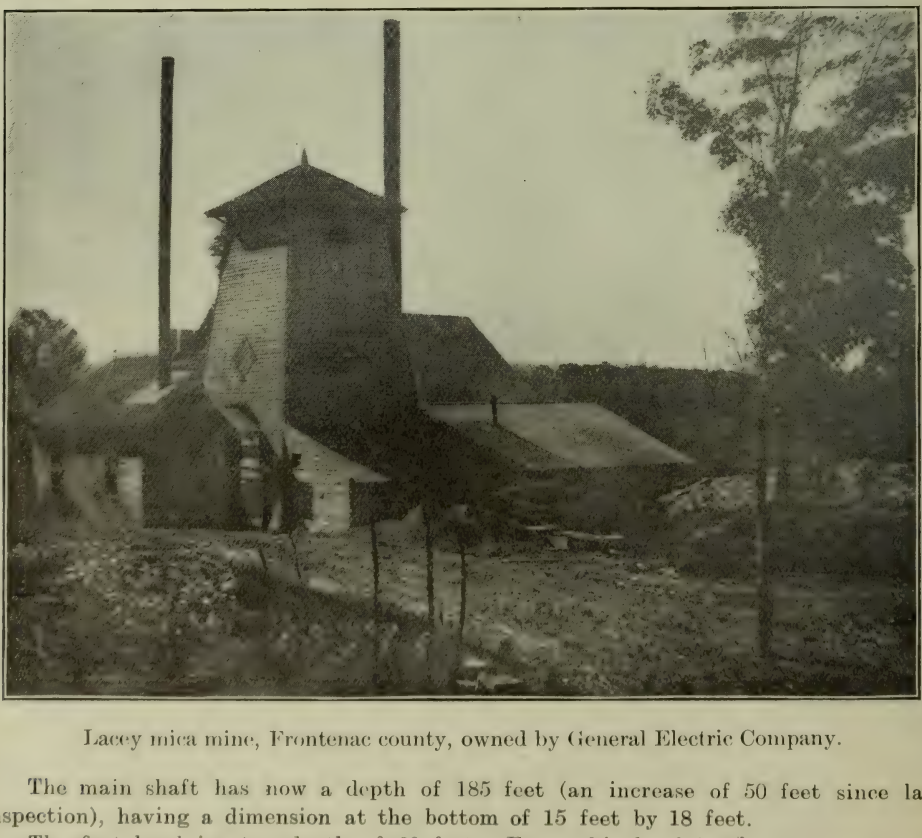
	Muscovite.	Phlogopite.	Biotite.
SiO_2	45.2	39.66	39.5
Al_2O_3	33.5	17.00	16.5
Fe_2O_3	2.7	0.27	5.
FeO	1.2	0.20	12.
MgO	1.	26.49	12.5
BaO	..	0.62	..
Na_2O	1.	0.60	0.7
K_2O	9.5	9.97	8.8
TiO_2	..	0.56	1.
F	0.5	2.24	1.
H_2O	4.5	2.99	2.8

Muscovite (white mica) has not been produced commercially in Ontario, although it is known to occur in several localities. Deposits have been found in the township of Methuen, Peterborough county, occurring in syenite dykes associated with corundum. This mica is, however, as a rule too hard for electrical purposes, and the deposits have not as yet been developed to any extent. A deposit of muscovite has been found near Mazinaw lake, Effingham township, county of Lennox. This deposit is in a pegmatite dike which has been traced for a couple of miles from surface outcroppings. Some of the mica is a very clear muscovite, but parts of the dike contain mica quite badly stained and spotted with iron.

General Electric Company

This company during the year 1904 operated the Lacey mine in Loughboro' township, and during the summer months carried on considerable prospecting work in other parts of the township, and also near Perth in the township of Burgess.

The Lacey mine has for the last few years ranked as the largest producer of mica in Ontario, and has probably produced the largest quantity of mica of any mine in Canada. The mine was opened about the year 1899 by J. W. Trousdale of Sydenham, who worked it under lease until the first of the year 1901, when it reverted to the owners, The General Electric Company of Schenectady, N. Y., who have since operated it with Mr. G. W. McNaughton, manager.



Lacey mica mine, Frontenac county, owned by General Electric Company.

The main shaft has now a depth of 185 feet (an increase of 50 feet since last inspection), having a dimension at the bottom of 15 feet by 18 feet.

The first level is at a depth of 60 feet. From this level in the southeast drift at 100 feet from the shaft a winze has been sunk to the third level, and a little stoping done.

The second level at a depth of 85 feet has a drift running northwest 45 feet. A crosscut is being driven in the hanging wall from the second level platform to cut a parallel vein of mica located by the diamond drill. A distance of 31 feet had been driven at the time of inspection. Since the inspection of the mine a large deposit of mica has been located by this crosscut northeast of the old ore body.

The third level at a depth of 95 feet has a drift southeast 130 feet, being an increase of 88 feet. The floor of the easterly drift from the main drift has been broken through to the level below.

The fourth level at a depth of 117 feet has two drifts running southeast of the shaft, the easterly one being 135 feet and the westerly 130 feet in length.

The fifth level (new) is at a depth of 140 feet with northwest drift 60 feet in length. Two drifts have also been run on this level southeast of the shaft. The easterly drift has a length of 135 feet and westerly 130 feet. The floor between the fourth and fifth levels in the easterly drift has been stoped out.

The sixth level at a depth of 165 feet has a southeast drift 60 feet and a northwest drift 40 feet in length.

Northwest of the shaft the mica has all been stoped out from the second to the fifth level. Timbers have been placed under the roof overhanging this stope, and pillars left between the stope and shaft. Stulls have been placed in the floor of the fourth level, which has been broken through, to thoroughly protect the lower workings.

The surface machinery consists of a class B Rand air-compressor, which furnishes 1,015 cubic feet of fresh air per minute at normal capacity; two Jenckes boilers of 70-h. p. capacity each, with feed water heater and pumps. A hose house has been built and small pump placed therein to pump water from the old Lacey pit for the compressor and for fire protection. The company also own a diamond drill, and some 2,000 feet of drilling has been done at the Lacey mine prospecting for new ore bodies and determining the extent of the old ones.

The General Electric Company carried on prospecting during the past year on the Canada Company's lot at Mud lake, Loughboro township, and on the Burns property, lot 11 and east half of 12 in the seventh concession, township of North Burgess. This lot adjoins the lot on which the Hanlan mine is situated.

Freeman Mica Mine

Richardson Bros. of Kingston worked all year on the Freeman property on lot 7 in the ninth concession of Loughboro township. There are three parallel veins. The mica in the middle vein is milky and badly twisted. A very fair quality is found in the parallel veins. A shaft 80 feet deep has been sunk and the vein stoped out for 40 feet. The mica was all cleaned at the mine. It is the intention of the management to begin work on the vein of black mica on the west side of the lake, as the demand for this quality is increasing.

Baby Mine

The Baby mine, about 14 miles from Perth, on lot 11 in the fifth concession of North Burgess township, was re-opened during the year. The mine was worked some years ago as a large open pit 15 to 20 feet across and 165 feet deep. A mining camp has been built and boiler and hoist installed.

The west half of lot 6 in the ninth concession of North Burgess was worked under lease by Messrs. Montgomery and Adams of Perth. A shaft 40 feet deep was sunk on the vein having a width of 6 feet. A short drift was run at the bottom of the shaft northwest along the vein. The mica is cleaned at the Adams trimming works at Perth.

Kent Bros

The operations of this firm are largely confined at the present time to their mine near Buckingham, Quebec. The Bob's lake mine in Bedford township was, however, worked until October of 1904, when it was temporarily closed. The mica produced from this mine was cleaned at the firm's mica works at the foot of Princess St., Kingston. The mica from their mine in Quebec is also sent here to be cleaned. There are seven men employed in thumb-trimming and twenty-two girls in thin-splitting the mica.

Messrs. Mills & Cunningham of Kingston worked an amber mica property on the north part of lot 9 in the second concession of South Sherbrooke township, county of Lanark, for some months during the year. The mica was found in a vein of calcite, which was considerably broken by faults and had been subjected to much pressure.

Prospecting was also done on lots 4 and 7 in the third concession, and lot 2 in the fourth concession of South Sherbrooke.

Mica Trimmimg Works at Ottawa

The General Electric Company have large works on the corner of Isabella and Elgin streets, Ottawa, which are fitted up with cutting knives, thin-splitting tables, and all appliances necessary for the production of mica in its marketable state. The mica from all the company's mines is shipped here for preparation. After preparation the mica is sent to the company's works at Schenectady, N.Y. A force of ninety, of whom fifty girls are engaged in thin-splitting, is employed under superintendent R. E. Nivison.

The Laurentide Mica Company have recently opened a large factory on the corner of Queen and Bridge streets. This company ship all their mica to the Westinghouse Company at Pittsburgh, Pa., for use in the manufacture of electrical machinery. Some of the mica is obtained from this company's own mine at Chelsea, Quebec, and the rest from independent producers in both Ontario and Quebec. A force of 175 girls is engaged in thin-splitting the mica, twenty-four on the knives, and ten thumb-trimming, under superintendent Chas. Girteau.

Eugene Munsell and Company have steadily employed an average of about twenty, nearly all girls, engaged in thin-splitting, under superintendent S. O. Fillion. Most of this mica is bought from the small producers of Ontario and Quebec.

PHOSPHATE OF LIME

The phosphate industry, which has been dormant in eastern Ontario for some years, received some attention from German chemists in 1904. A large number of phosphate properties were purchased and a company formed known as the Dominion Improvement and Development Company, with head office at Hamburg, and branch office in New York. Work was done last season on lot 13 in the sixth concession of North Burgess. A shaft 20 feet square was sunk and a quantity of mixed phosphate and rock taken out Camp buildings were put up and preparation made for the production of a larger tonnage of ore.

GRAPHITE

The Black Diamond graphite mine was leased from the Ontario Graphite Company, Limited, by Mr. Rinaldo McConnell of Ottawa, and has been operated by him since 1st May, 1904. Under Mr. McConnell's management a dam was built to enable the old workings to be unwatered, which owing to a cave-in, had been filled by water

from the lake. The mine was then pumped out, but the workings were found to be in such a dangerous condition that they were abandoned, and a new shaft begun 100 feet southwest of the old shaft and running parallel with the old workings. The shaft is sunk on an incline of thirty degrees, following the dip of the vein, and has a depth of 170 feet. Some ore has been stoped from the south side of the shaft.

The shaft is fitted with skip-track and ore is hoisted by skip driven by duplex cylinder single drum hoist operated by compressed air. The skip-track and the way for the men to enter the mine was in the same shaft and not separated by partition as required by the Mines Act.

The new power plant on the Madawaska river, two miles from the mine, has been completed, furnishing power to run compressor and mill.

The mill was closed at the time of inspection in March 1905, as the management was installing a new system of air separation. A force of thirty men was employed under superintendent Allan McDonell.

A new stamp is being successfully used, which greatly increases the output. This is conical in form, fitting in a mortar of the same shape.

The McConnell graphite mine in North Elmsley township, county of Lanark, about seven miles north of Perth, which was closed in 1903, has recently been opened, and work is expected to be carried on the coming summer in both mine and mill.

ACTINOLITE AND ASBESTOS

The operations of Mr. Joseph James and the International Asbestos Company in the grinding of actinolite and production of short fibre asbestos was brought to a standstill last June by the blowing out of their mill dam by a lumber company. As a consequence, all operations in that line have ceased, pending a suit regarding the utilization of the water power.

This industry, which is one of the oldest mining industries in continuous operation in the Province, has recently received attention from operators both in England and the United States. It is to be hoped that the difficulty now hampering the business will soon be removed.

TALC

The Henderson talc mine on lot 14 in the fourteenth concession of the township of Huntingdon, was operated for two months during 1904 by Mr. S. Wellington of Madoc, who had the property under lease. A shaft had previously been sunk to a depth of 53 feet and short drifts run in both directions along the deposit at a depth of 35 feet, as well as some crosscutting done, proving it to have a width of 20 feet. During the time of operation in the past summer no new development work was done.

A quantity of talc was mined from the drifts by both underhand and overhand stoping. The best grade product was shipped to Newark, N. J.

CALCIUM CARBIDE

With the increased use of acetylene gas for lighting purposes in small towns and villages, which are not supplied with electric light and gas plants, the manufacture of calcium carbide has been placed on a firm basis, and a steady demand is assured.

The Ottawa Carbide Company, with works at Ottawa, have a total of twenty furnaces. At the time of the writer's visit only five to eight furnaces were in operation, owing to the low water supply. The process for the formation of carbide consists of the fusion of lime and coke in an electric furnace according to the reaction. $CaO + 3\ C = CaC2 + CO$. The fusion requires a current of 1,500 amperes and a voltage of 75. This must be kept constant, which is accomplished by raising or lower-

ing the upper electrode. The lower electrode is a block of carbon let into an iron base plate, while the upper electrode is a suspended carbon block.

After fusion the furnace is dumped and the unfused part returned to the furnace. On being cooled, the scale is taken off the fused mass by means of pneumatic hammers or chisels. The carbide is then crushed to a uniform size and packed in tins containing 100 pounds. The limestone used in the production of the lime (CaO) is from Welland county. It is very pure, low in magnesia and belongs to the Corniferous formation. It is quarried at Port Colborne and Skerkston, and is also burnt there by natural gas as fuel. An analysis shows the following percentage:

Silica	2.00
Alumina and ferric oxide	1.10
Lime	51.00
Magnesia	1.10
Phosphorus	.015
Sulphur	.05

The company at Ottawa produce their own electric power.

The calcium carbide factory at Merritton, Welland county, was also in operation during the year.

PETROLEUM AND NATURAL GAS

BY E T CORKILL

The past and present year have seen renewed activity in the petroleum fields of southwestern Ontario. This activity is due to the finding of two new oil fields, namely, the Moore township field in Lambton county, and the Leamington field in Mersea township, county of Essex. The first well in the Moore township field was brought in in July 1904, on lot 3 in the tenth concession, and in the Leamington field on 1st June 1902, on the farm of Gustavus Straubel, lot 238, Talbot Road.

In March 1905, under instructions from Mr. T. W. Gibson, Director of the Bureau of Mines, the writer paid a visit to nearly all the oil and gas producing fields of southwestern Ontario, for the purpose of procuring as full and authentic information as possible regarding the new oil and gas fields that were being opened up, as well as of ascertaining any new developments that were being made in the older fields.

Two very complete reports dealing with the southwestern peninsula have been published by the Geological Survey of Canada. The first was The Geology of Canada (1863) in which are summed up the results of the observations on the geology of the region made by Logan, Hunt and other investigators. In the Report of the Geological Survey of 1890-91, Mr. H. P. H. Brummell takes up the occurrence of petroleum and natural gas in Ontario, giving logs of a great number of wells and also sections illustrating the sequence of the Palaeozoic formations in Ontario.

Individual fields have been described in recent reports of the Bureau of Mines. In the Thirteenth Report, Part II, the chief geological divisions and outcropping rocks are shown. In Vols. III and VI of the Journal of the Canadian Mining Institute, Mr. Eugene Coste has published papers on Natural Gas in Ontario.

PETROLEUM FIELDS

The production of petroleum in Ontario has so far been largely confined to the county of Lambton. The first oil was found in this country about the year 1862, a few years after the great oil strikes in the United States. There have been in the county of Lambton alone about eleven thousand producing wells, some of which have been yielding oil for over forty years. At the present time there are 8,100 wells in operation at Petrolea, and 1,000 at Oil Springs. Probably the most remarkable thing about this field is its permanency of flow and the small average yield per well. One group of 100 wells the writer visited, produced 150 barrels a month, all the wells being operated from a central pumping station.

Petroleum has for some years been known to occur on Manitoulin Island, in fact it is recorded that the first oil found in Canada was that discovered on this island. A company was formed in 1865 to bore for oil, but the venture apparently was not successful. At the present time more drilling is being done there, with prospects of better results.

Oil has also been found in other counties in southwestern Ontario.

About seven years ago petroleum was struck in the township of Dutton, Elgin county. The field here is small, comprising about 400 acres, but the wells are shallow and have a steady production. The oil is obtained from the Corniferous at a depth of 440 feet.

In Kent county small fields have been located in different parts. In Raleigh township on lot 18, in the twelfth concession, a flowing well was struck in November of 1902, known as the "Gurd gusher." Very few wells however were productive in this field. The "Gurd" well has ceased to flow, and pumping operations have been given up in the field. The Wheatley field in the township of Romney has a steady production, though a small average yield per well.

The Bothwell field in Zone township, county of Kent, has between 200 and 300 producing wells. This field is considered a good paying proposition. It has a small production per well, but the output last year, according to Mr. Kennedy, secretary of the United Oil and Gas Company, did not depreciate two per cent., as compared with the previous twelvemonth. The wells are quite shallow, averaging in depth about 600 feet, and formations drilled through are very similar to those in the Petrolea field.

North of the Bothwell field in Euphemia township is another group of wells with a small production. The wells, however, are very shallow, averaging 370 feet (the thickness of drift being 53 feet).

Essex county, which for some years was a large producer of natural gas, bids fair now, like the Petrolea field, to become an important producer of petroleum.

Oil had not been found in commercial quantities in Ontario, until a very few years ago, in any formation but the Corniferous, and oil men had almost become convinced that drilling to greater depths was useless. In the spring of 1902 a company was formed in the town of Leamington to explore for gas and oil in that section. A well was sunk on lot 238, Talbot road, and oil was struck at a depth of 1,074 feet on 1st June 1902, in a formation previously not recognized as a prolific oil stratum, namely the Guelph formation. This formation is a very porous dolomitic limestone, and has been known for years as a producer of natural gas in this county. No very large oil producers, however, were found until 1905. This year has witnessed the bringing in, in this field, of some large flowing wells, the largest reported as yet being the Hickey No. 4, which started off with a flow of 1,200 barrels per day; this it maintained for nearly three days, and then gradually diminished day by day until it is now down to about 200 barrels a day, but still flowing. On 10th April a gusher was truck on lot 9, concession 4, Mersea township, on the farm of Patrick Smith. This is also stated to be a very large producer. The exceeding porosity of the productive sand in this field points to a good prospect for a producing oil field, if the oil is not too near the salt water. At present the oil sent to the refinery at Sarnia contains considerable water. In one month in the early part of 1905, 3,000 barrels of oil were shipped from this field to the refinery.

Another new field was found in 1902-03, the productive area being a still lower horizon in the geological scale than the formation in which the oil is found in the Leamington field. This field is situated in the county of Brant, near the city of Brantford, having its productive area in the Medina. Several oil wells have been brought in, with small production. Gas is also found along with the oil in most of the wells. A well has just been drilled to the Trenton in this field, the log of which is given in another part of this report.

NATURAL GAS FIELDS

The production of natural gas in Ontario is now limited almost entirely to the counties of Haldimand and Welland. The Essex field, which was so prolific a source of gas some years ago, has almost entirely ceased to produce, hardly sufficient gas

being obtained to supply the towns in proximity to the old fields. In October 1901 the exportation of gas to Detroit was stopped by the Ontario Government by Order-in-Council revoking the license of occupation which authorized the exporting company to use the bed of the Detroit river for the purposes of its pipe line, in the hope that by so doing the life of the field would be prolonged. This, however, did not have the desired effect, and the field is now practically abandoned. Seven gas wells were drilled north of this field in 1904, three or four of which are producing from 3,000 to 90,000 feet per day. These wells are situated practically in the oil field. A rock pressure of 398 lb. was recorded. The gas is used to supply the town of Leamington, and also for drilling and pumping in the oil field.

The first well in the Welland field was struck in August 1889, on lot 35 of the third concession from lake Erie, in Bertie township, seven miles east of Port Colborne. This well was drilled by the Provincial Natural Gas and Fuel Company of Ontario, Limited. The gas was struck in a white sandstone of the Medina formation at 836 feet. Previous to this, however, a few wells had been sunk at Port Colborne and vicinity, the first well being put down in August of 1886. These wells were small producers, 70,000 feet per day being the largest flow obtained.

From fourteen wells put down by the Provincial Natural Gas and Fuel Company a supply of 30,895,000 cubic feet of gas per day was obtained. This company has supplied Buffalo since January 1891, and during the past year has constructed 8-inch high pressure pipe lines to Niagara and Chippewa, the former twelve miles in length, and the latter one and one-half miles. Gas is also delivered at Bridgeburg, Fort Erie, Sherkston, Stevensville, Crystal Beach and other points along the lake shore, and to any farmer applying for it along any of their lines.

The Winger field, in Wainfleet township, was opened in 1903, and has now eight producing wells which have a rock pressure of 260 lb. Another field opened by the same company during 1904 is in the centre of the township of Crowland. In this field the gas is found in the Clinton formation.

The Mutual Natural Gas Company, Limited, of Port Colborne, controls a field near that town, with an area two miles east, six miles north and three miles west. The northern part of this is new territory opened up only two years ago, and is the most productive. The gas is here found in the Clinton. The company has 35 producing wells and supplies the towns of Port Colborne, Humberstone and Welland. Just west of the Mutual Company's properties the Welland County Lime Works Company utilizes the gas in the burning of lime from wells it has just put down.

Northwest of Dunnville in the township of Canborough, Haldimand county, the Dominion Natural Gas Company has put down 34 wells in what is known as the Attercliffe field, and five wells outside of this field. The wells produce from 25,000 to 75,000 cubic feet per well. An 8-inch high pressure pipe line has been constructed to Hamilton and Dundas from this field. A pressure of 60 lb. is attained at Dundas. The Citizens' Natural Gas Company have nine producing wells in Attercliffe field and supply gas to consumers in the town of Dunnville.

ORIGIN OF OIL AND GAS

In dealing with the origin of petroleum and natural gas the aim of the writer is solely to treat the subject from the literature of the subject by giving extracts from those writings in which the chief theories have been advanced or supported.

Theories of Inorganic Origin

Two of the first writers to advocate the theory of inorganic origin were M. Berthelot and M. Mendeljeff. A paper was published by M. Berthelot in 1866, wherein he says:

"If in accordance with an hypothesis recently announced by M. Daubre, it is to be admitted that the terrestrial mass contains free alkali metals in its interior, this hypothesis alone, together with experiments that I have lately published, furnishes

almost of necessity a method of explaining the formation of carbides of hydrogen. According to my experiments, when carbonic acid, which everywhere infiltrates the terrestrial crust, comes in contact with the alkali metals at a high temperature, acetylides are formed. These same acetylides also result from contact of the earthy carbonates with the alkali metals even below a dull-red heat.

"Now the alkaline acetylides thus produced could be subjected to the action of vapor of water; free acetylene would result if the products were removed immediately from the influence of heat and of hydrogen (produced at the same time by the reaction of water upon the free metals) and the other bodies which are found present. But in consequence of the different conditions the actylene would not exist, as has been proved by my recent experiments. In its place we obtain either the products of its condensation, which approach the bitumens and tars, or the products of the reaction of hydrogen upon those bodies already condensed, that is to say, more hydrogenated carbides. For example, hydrogen reacting upon the acetylene engenders ethylene and hydride of ethylene. A new reaction of the hydrogen either upon the polymeres of acetylene or upon those of ethylene would engender formenic carbides, the same as those which constitute American petroleum. An almost unlimited diversity in the reaction is here possible, according to the temperature and the bodies present."

In 1877 M. Mendeljeff published a paper setting forth his theories on the Inorganic Origin of Petroleum and Natural Gas. From a resumè of his paper the following is an extract:—

"Admitting the existence of metallic carbides, it is easy to find an explanation not only for the origin of petroleum, but also for the manner of its appearance in the places where the terrestrial strata, at the time of their elevation into mountain chains, ought to be filled with crevices to their centre. These crevices have admitted water to these metallic carbides. The action of water upon the metallic carbides at an elevated temperature and under a high pressure, has generated metallic oxides and saturated hydrocarbons, which being transported by aqueous vapor, have reached those strata where they would easily condense and impregnate beds of sandstone, which have the property of imbibing great quantities of mineral oil."

Also in Mendeljeff's "Principles of Chemistry," vol. I, page 364:

"As during the process of the dry distillation of wood, seaweed and similar vegetable debris, and also when fats are decomposed by the action of heat (in closed vessels) hydrocarbons similar to naphtha are formed, it was natural that this should have been turned to account to explain the formation of the latter. But the hypothesis of the formation of naphtha from vegetable inevitably assumes coal to be the chief element of decomposition, and naphtha is met with in Pennsylvania and Canada, in the Silurian and Devonian strata, which do not contain coal, and correspond to an epoch not abounding in organic matter. If we ascribe the derivation of naphtha to the decomposition of fat (adipose animal fat) we encounter three almost insuperable difficulties: (1) Animal remains would furnish a great deal of nitrogenous matter, whilst there is but very little in naphtha; (2) the enormous amount of naphtha already discovered as compared with the insignificant amount of fat in the animal carcase; (3) the source of naphtha always running parallel to mountain chains is completely inexplicable."

"Another fundamental reason is the consideration of the mean density of the earth. Cavendish, Airy, Cornu, and many others who investigated the subject by various methods, found that, taking water as 1, the mean density of the arth is nearly 5.5. As at the surface water and all rocks (sand, clay, limestone, granite, etc.) have a density less than 3, it is evident (as solids are but slightly compressible even under the greatest pressure) that inside the earth there are substances of a greater density, namely, not less than 7 or 8. . . . . . For this reason it is possible that the interior of the earth contains iron in a metallic state."

Many other eminent chemists and geologists have made investigations and have written in support of the Inorganic theory. Mr. Eugene Coste, in the Journal of the Canadian Mining Institute, Vols III and VI, has published two papers dealing more particularly with the occurrences in Ontario, and the evidence here furnished in support of this theory. Mr. Coste points out the following:—

"1st. In the Archean rocks we find carbon under the form of graphite in gneisses (1) in pegmatite dikes, in granites, (2) gabbros, (3) and other rocks, the igneous origin of which is undeniable.

"2nd. In the crystals of igneous gneisses and of most granites and other eruptive rocks, gaseous and liquid inclusions are most abundantly found, and these are very

often constituted by carbonic acid and hydrocarbons, and also often contain chloride of sodium in solution or in minute crystals.

"3rd. Petroleum, or semi-liquid or solid bitumens have often been noticed and cited by many observers as occurring in traps, basalts, or other igneous rocks, as for instance by Sir William Logan[1] in a green stone dike at Tar Point, Gaspé, Province of Quebec: by Mr. Rateau in trachytes in Galicia, and by Professor Arthur Lakes[2] in injected volcanic dikes in Archelutu county, Colorado.

"4th. Volcanic rocks forming vertical necks and pipes across horizontal strata. and containing carbon in the pure form of diamonds, are also well known to constitute in South Africa the deposits of these precious stones. These diamentiferous volcanic necks and pipes also contain large cavities filled with gaseous hydrocarbons as pointed out by Mr. Moulle.

"5th. We now come to the hydrocarbon and carbonic acid in volcanic manifestations of to-day. Not later than a few months ago the civilized world was suddenly startled and horrified at the report that an explosion of Mount Pelee had wiped away in a few minutes the entire population of St. Pierre, Martinique Island. From the account of the catastrophe then published. it is quite certain that a fearful blast or tornado of gases suddenly shot from the side of the volcano, asphyxiating and burning in a moment 30,000 people. Nothing else, we submit, but gas could carry death so suddenly to so many thousand people, inside and outside their houses over a whole city."

To quote further from Mr.Coste:[3]

"It is indeed quite clear that one believing in the organic theory of the origin of natural gas and petroleum would naturally consider that there might be natural gas or petroleum deposits under any part of the peninsula of southwestern Ontario between the Georgian bay, lake Huron and lake St. Clair to the northwest and lake Erie and lake Ontario to the southeast, as the whole of that large section of the country is underlaid with Devonian and Silurian strata more or less fossiliferous; and it would be and has been impossible to any one following that organic origin theory to localize any particular district of that peninsula where these hydrocarbon products should be found by drilling. In fact, according to that theory, if found in one place, these products should be found in almost any other part of the peninsula. On the other hand, for one accepting, as I did, the volcanic origin of these products as gaseous emanations from the interior of the earth along certain fissured and fractured zones of the crust of the earth, it was possible to select in southwestern Ontario several likely new gas fields by mapping out the probable continuation in Canada of these fissured and fractured zones from other gas and oil fields already located and developed on the same zones in the United States."

Theories of Organic Origin

The organic theory of the origin of natural gas and petroleum is supported by those who believe that these substances are derived from vegetable and animal matter contained in the rocks in which they are found or in associated strata. Compounds similar to, or identical with, petroleum and natural gas, are derived by the process of destructive distillation from both vegetable and animal substances. The manufacture of artificial gas from bituminous coal is also a familiar illustration of the possibilities in this direction. Bituminous shale may be substituted for coal in the manufacture, and may be made to yield a series of these bituminous products, including both petroleum and gas.

Beyond the fact that petroleum and natural gas are derived from animal and vegetable remains, there is little agreement among the most responsible authorities as to their particular mode of origin. Two views, however, have become especially prominent. These are that hydrocarbons were formed by (1) the primary distillation of vegetable or animal remains, and (2) a second distillation or decomposition of organic remains at some period subsequent to their deposition.

Dr. E. Orton thus defines these different opinions:[4]

"The first view is that petroleum is in large part derived from the primary decomposition of organic matter that was stored in or associated with. the strata that now

1 Geology of Canada, 1863, pp. 402 and 789. 2 Min. Resources of the U. S., 1901, p. 561
3 Journal Can. Min. Inst., Vol. III. p. 79. 4 Geol. Survey of Ohio, Vol. VI.

contain it. According to this view the decomposition was mainly effected *in situ*, and the product resulting is, therefore, mainly indigenous to the rock in which it is found. The last feature is seized upon in most popular statements, and a theory of indigenous origin is made to include most beliefs of this class. It must be borne in mind, however, that no author is to be found who holds strictly and consistently to such indigenous origin, but the name can still be used as a general designation without harm.

"The second view is, that petroleum is derived from the secondary decomposition of organic matter stored in the rocks. It supposes the original vegetable and animal matter to have suffered a partial transformation and to be now held in the rocks as a hydrogen compound, from which, by a process of distillation, oil and gas are derived. The so-called bituminous shales are counted the chief sources of these products. After distillation it is held that the gas and oil are mainly carried upward by hydrostatic pressure to some overlying porous stratum that serves as a reservoir. This class can be conveniently grouped under the name of the distillation theory."

The Primary Decomposition Theory

The greatest exponent of the theory that petroleum is derived from the primary decomposition of organic tissues is Dr. T. Sterry Hunt. He urges that petroleum mainly originates in and is obtained from limestones. When found in limestones he counts the oil indigenous, but when found elsewhere as in sandstones and conglomerate, he counts it adventitious and he then refers it to underlying limestones. In speaking of the oil fields of Canada he says:[5]

"The facts observed in this locality appear to show that the petroleum of the substance which has given rise to it was deposited in the bed in which it is now found at the formation of the rock. We may suppose in these oil bearing beds an accumulation of organic matters, whose decomposition in the midst of a marine calcareous deposit, has resulted in their complete transformation into petroleum, which has found a lodgment in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds forbids the idea of the introduction of the oil into these strata either by distillation or by infiltration. The same observations apply to the Trenton limestone, and if it shall be hereafter shown that the source of petroleum (as distinguished from asphalt) in other regions is to be found in marine fossiliferous limestone, a step will have been made toward a knowledge of the chemical conditions necessary to its formation."

He also says:[6]

"In opposition to the generally received view which supposes the oil to originate from a slow destructive distillation of the black pyroschists, belonging to the middle and upper Devonian, I have maintained that it exists, ready found, in the limestones below."

Again:[7]

"It has already been shown that the petroleum of Canada occurs in two distinct horizons; the one in the limestones of the Trenton group, and the other in those of the Corniferous formation. To this it must now be added, that the petroleum of Gaspé probably belongs to an intermediate position, and it to be referred to limestones of Upper Silurian age."

Also in writing of a dolomite in the Niagara formation met with near Chicago, Illinois, he says:

"A layer of this oleiferous dolomite, one mile square and one foot thick will contain 1,184,832 cubic feet of petroleum, equal to 8,850,069 gallons of 231 cubic inches and to 221,247 barrels of forty gallons each. Taking the minimum thickness of 35 feet assigned by Mr. Worthen to the oil-bearing rock at Chicago, we have in each square mile of it 7,743,745 barrels of petroleum. . . . . . With such sources ready formed in the earth's crust, it seems to me, to say the least, unphilosophical to search elsewhere for the origin of petroleum, and to suppose it to be derived by some unexplained process from rocks which are destitute of this substance."

Another important paper on petroleum formation is Wall's report on the Trinidad asphalt. He says:[8]

5 American Journal of Science, Vol. XXXV., p. 168. 6 American Journal of Science, Vol. XLVI., p. 361. 7 Geology of Canada 1863, page 786. 8 Quart. Journal Geol. Soc. XVI., p. 467.

"When *in situ* the asphalt is confined to particular strata which were originally shales containing a certain proportion of vegetable debris. The organic matter has undergone a special mineralization producing bituminous in place of ordinary anthraciferous substances. This operation is not attributable to heat nor to the nature of distillation, but is due to chemical reaction at the ordinary temperature and under the normal conditions of the climate."

Origin by Secondary Decomposition.

This theory is upheld by Messrs. J. S. Newberry and S. F. Peckham, both of whom advance somewhat different opinions, though acknowledging that petroleum and gas are the product of the secondary rather than of the primary decomposition of organic substances. The former contends that the distillation is continuous and at a low temperature, while the latter holds to the view that the distillation was effected by the heat that accompanied the elevation of the Appalachian Mountain System.

In his paper on the "Rock Oils of Ohio," Newberry says:[9]

"The precise process by which petroleum is evolved from the carbonaceous matter contained in the rocks which furnish it is not yet fully known, because we cannot in ordinary circumstances inspect it. We may fairly infer, however, that it is a distillation, though generally performed at a low temperature."

Again he says:[10]

"The origin of the two hydrocarbons is the same, and they are evolved simultaneously by the spontaneous distillation of carbonaceous rocks. Where the oil and gas producing rocks and those overlying them are solid and compact, decomposition of the organic matter they contain takes place very slowly and the escape of the reacting hydrocarbons is almost impossible. Where they are more or less shaken up, decomposition takes place more rapidly; reservoirs are opened to receive the oil and gas, and fissures are produced which serve for their escape to the surface."

Also in the same volume, page 158, he says:

"We have in the Huron shale a vast repository of solid hydro-carbonaceous matter which may be made to yield ten to twenty gallons of oil to the ton by artificial distillation. Like all other organic matter this is constantly undergoing spontaneous distillation, except where hermetically sealed deep under rock and water. This results in the formation of oil and gas, closely resembling those we make artificially from the same substance, the manufactured differing from the natural products only because we cannot imitate accurately the process of nature."

From the preceding extracts Newberry's theory may be summarized as follows:

Oil and gas are the result of a continuous and spontaneous distillation of the bituminous matter of certain shales, from which the greater part of the two hydrocarbons is obtained.

A few brief extracts will be sufficient to state the theory advanced by Peckham. He says:[11]

"Bitumens are not the product of the high temperatures and violent action of volcanoes, but of the slow and gentle changes at low temperature, due to metamorphic action upon strata buried at immense depths. . . The alteration, due to the combined action of heat, steam and pressure that involved the formations of the Appalachian system from Point Gaspé, in Canada, to Lookout Mountains in Tennessee, involving the Carboniferous and earlier strata, distorting and folding them, and converting the coal into anthracite, and the clays into crystalline schists, along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died out farther and farther from the surface. The great beds of shale and limestone containing fucoids, animal remains and even indigenous petroleum must have been invaded by this heat action to a greater or less degree."

Dr. Orton says:[12]

"The double origin of petroleum from both limestones and shales—and it is not necessary to exclude sandstones from the list of possible sources—deserves to be universally accepted. In confirmation of this double origin, it is coming to be recognized

9 Ohio Agricultural Report, 1859. 10 Geol. Surv. of Ohio, Vol. I., 1873, p. 192.

11 Census of the United States, Vol. X. 12 Geol. Survey of Ohio, Vol. VI., p. 71.

that the oil and gas derived from these two sources generally differ from each other in noticeable respects. The oil and gas derived from limestones contain larger proportions of sulphur and nitrogen than are found in the oil and gas of the shales."

Rock Pressure of Gas

In connection with the origin of petroleum and natural gas, pressure is a very important factor to be considered. Four theories have been advanced, which explain the pressure by:

(1) The pressure due to the expansive nature of the resulting gas from the decomposition or distillation of organic remains.

(2) The pressure due to the weight of the overlying rocks.

(3) Hydrostatic water pressure.

(4) Pressure due to gaseous emanations from below.

The last two are probably the most important, and the two which are chiefly upheld by geologists at the present time.

The second theory is upheld by those who claim that the weight of the overlying rocks exerts a pressure which is available for driving the accumulation of gas out of the rocks that contain them. This would only be possible were the rock in a crushed state, as otherwise no pressure would be exerted on the gas contained in the spaces between the grains.

The third theory claims that the cause of the flow of both petroleum and natural gas is due to the pressure of a column of water depending for its height on the depth of the strata in which these substances occur. Prof. Orton upheld this theory and explained it to be similar in principle to the flow of water from artesian wells. The amount of pressure would therefore depend on the height to which the water column is raised, in case continuous porosity of the stratum can be assured.

The fourth theory is upheld by those who believe in the inorganic origin of natural gas and petroleum. Mr. Coste writes:[13]

"In every field where gas is found in several strata, the highest pressure is always recorded in the lowest or deepest strata. For instance, in the Welland county field the rock pressure of the gas was 300 lb. in the Guelph dolomite; 400 lb. in the Clinton; 525 lb. in the Medina white sand; and 1,000 lb. in the Trenton limestone; these enormous pressures decreasing as the gas travels up from below by friction through the small fissures and the small pores of the 'sands,' we submit, cannot be explained any other way than by a volcanic source from below."

THE GEOLOGICAL SCALE OF ONTARIO

In the geological formations of Ontario the possible productive areas of petroleum and natural gas comprise the Palaeozoic rocks which consist of strata of Devonian, Silurian, Cambro-Silurian and Cambrian age. Overlying these is drift of glacial and recent deposits. The thickness here assigned to each is the comparative thickness of the strata of the Welland field to that of the Lambton field, taken from an average of the deep wells put down in those fields.

RECENT AND GLACIAL DRIFT.	Marls, clay Boulder clay	50-- 125 feet.
DEVONIAN	Portage and Chemung	0-- 100 "
	Hamilton	0-- 350 "
	Corniferous	0-- 250 "
	Oriskany	0— 25 "
SILURIAN	Lower Helderberg Onondaga	300--1580 " (at Petrolea.)
	Guelph Niagara	290--435 feet.
	Clinton	30--155 "
	Medina	950—300 "
GAMBRO-SILURIAN	Hudson River	730--350 "
	Utica	175—350 "
	Trenton Bird's Eye and Black River Chazy Calciferous Potsdam	730—750 "

[13] Journal Can. Min. Inst., Vol. III., p. 83.

Trenton Formation

This formation is the lowest in the geological scale in which either gas or oil has been found in any quantity in Ontario. The outcrops of the Trenton and other formations in Palaeozoic groups in Ontario have been described in the Thirteenth Report of the Bureau of Mines, Part II. Sections of these formations are given in the 1863 Report of the Geology of Canada.

A section of the Trenton in the vicinity of Montreal is as follows:[14]

	Feet.
"Black bituminous nodular limestones in beds varying from two to four inches separated by layers of black bituminous shale of from one to two inches thick. The beds are highly fossiliferous	10
Gray bituminous granular limestone in beds of from three to eighteen inches at the bottom, passing into black nodular bituminous limestone at the top, interstratified with black bituminous shale in irregular layers of from one to three inches	10
Gray granular bituminous limestone of the same character as before in massive beds of from ten inches to two feet thick	10
Black and dark gray bituminous nodular limestone in beds varying from two to eight inches in thickness	150
Black bituminous compact limestone containing about ten per cent. of argillaceous matter	350
	530

In the southwestern part of Ontario drilling has reached the Trenton in Lambton, Essex, Brant, Welland and Elgin counties. A little gas and oil was struck in this formation in Essex county, and a high pressure of gas obtained in one well drilled in Welland county. Near where the Trenton outcrops on Manitoulin island, small quantities of oil have been found at depths of from 150 to 250 feet.

Utica Formation

This formation consists of dark brownish-black shales, very brittle, interstratified with occasional beds of compact brownish limestone. The shales yield bitumen by distillation. They overlie the Trenton and have a thickness varying from 175 to 350 feet. The upper boundary of the Utica is not always distinct, as the Hudson River shale that overlies it sometimes graduates into it in color and appearance.

A section of this formation in ascending order gives:[15]

	Feet.
"Black brittle bituminous shale	19
Black brittle bituminous shale with two bands of yellow-weathering limestone, black within, probably magnesian, and fit for hydraulic purposes	8
Black brittle bituminous shale	23
Black brittle bituminous shale, breaking into small fragments in consequence of an imperfect cleavage independent of the bedding	11
Black brittle bituminous shale with Graptolithus pristis	245
Gray hard sandstone, interstratified with bands of black shale	5
Black brittle bituminous shale, interstratified with beds of sandstone	7
	318

Hudson River Formation

This consists of greenish and bluish arenaceous shales interstratified with dark gray arenaceous shales and light gray sandstone. With them are associated some few beds of arenaceous conglomerate with calcareous pebbles. These beds vary from 730 feet in thickness in Welland county to 350 feet in Essex county.

Medina Formation

The gray sandstone of the Hudson River passes into the red sandstone and shales of the Medina. A section of the Medina in Welland county gives in ascending order:

	Feet.
Red shales	830
White sandstone	18
Blue shales	12
White sandstone	10
Red sandstone and shales	73

[14] Geology of Canada, 1863, p. 137. [15] Geology of Canada, 1863, p. 198.

Gas has been found in three horizons in the Medina, namely: 1. In the upper part of the red Medina sandstone. 2. In the upper white Medina sandstone. 3. In the lower white Medina sandstone.

Clinton Formation

On the Niagara river the Clinton is limited to a few feet, but gradually augments in thickness to the northward. It consists chiefly of thin-bedded white and gray limestones. Gas in found in one horizon in the Clinton in Welland county, namely, about ten feet below its surface. Gas and oil have been found in this formation in small quantities in Ohio.

Niagara Formation

The Clinton formation is generally described as being overlaid by the blue shales of the Niagara. These shales, however, thin out and disappear to the northward, and the shales are therefore included in the Niagara.

A section of the Niagara seen in the cutting of the Welland canal near Thorold is as follows in ascending order:

	Feet.
Bluish black magnesian limestone	10
Gray, coarse-grained sub-crystalline limestone	10
Bluish black bituminous shale with thin bands of impure limestone	55
Bluish gray argillaceous limestone	8
Dark bluish bituminous limestone	8
Light and dark gray magnesian limestone in beds varying from six to ten feet in thickness	26
Bluish bituminous limestone holding many fossils, principally corals	7
	124

Guelph Formation

These strata consist of a magnesian limestone, massive or thin-bedded. It is very porous with small drusy cavities, and is rich in fossils, the Megalomus Canadensis being the characteristic one. The dolomites at the top are bluish in color succeeded by white, yellowish white and grayish white. Gas has for some years been derived from the upper beds of the Guelph dolomite in Essex county, but oil was not known to occur in any quantity in this formation until 1904, when it was struck near Leamington.

Onondaga and Lower Helderberg

At the base this formation consists of red shales occasionally marked by green bands and spots. This first division is overlaid by greenish shales and marls. These strata abound in small veins and nodules of gypsum and readily disintegrate when exposed to the air. The third division, which is the true gypsum-bearing portion, consists of gray or drab colored magnesian limestones with grayish and greenish shales including two ranges of interstratified masses of gypsum. The upper division is a limestone with columnar markings on the surface of the beds. In Canada the Onondaga formation belongs chiefly to the upper portion. This consists of dolomites and soft crumbling shales which are greenish and sometimes dark brown or bluish in color and are often dolomitic. The dolomites are mostly of a yellowish brown or drab color, and are in beds seldom exceeding a foot in thickness. Some beds of bluish dolomites are also met with.

The lower beds of this formation in Lambton county are made up of what we may call the Salina. In some sections this reaches a thickness of about 800 feet, composed largely of salt interbedded with dolomite, the salt having a total thickness of some 700 feet.

Oriskany Formation

The Oriskany sandstone is a band of white or yellowish rather coarse and sharp-grained, slightly calcareous sandstone, varying in thickness from an inch to thirty feet.

Corniferous Formation

This formation is composed largely of bituminous limestones holding a large amount of chert or hornstone. The lower portion consists of beds of a light gray limestone. The upper portion is a limestone of compact texture and varies in color from drab and light gray through different shades of blue to black. The Corniferous was until very recntly the only oil-bearing formation in southwestern Ontario. Oil has been found in one horizon in this formation in what is termed the "lower lime." This is at a depth of about 65 feet in the formation. The formation has a total thickness of about 200 feet.

Hamilton Formation

This formation in New York state is divided into, in ascending order:

(1) Marcellus shales, (2) Hamilton group, (3) Tully limestone, (4) Genesee slates.

(1) The Marcellus shale is a black or brown bituminous shale or pyroschist, often pyritiferous, and closely resembling the Utica formation. The lower portion contains thin layers of dark colored impure fossiliferous limestone. In the upper part the shales are destitute of organic remains and lighter in color, becoming olive-gray and passing into the succeeding formation.

(2) The Hamilton group consists of a series of olive-colored or bluish calcareo-arenaceous and argillaceous shales weathering to ash gray or brown.

This, according to Mr. Hall, consists in ascending order of:

	Feet.
Olive shales	80
Coarse grained shales with a hard calcareous stratum at the top	40
Bluish and grayish blue very fossiliferous shales with large numbers of atrypa, spirifera and strophomena	90
	210

(3) The Tully limestone is a blackish blue concretionary fossilferous stratum, which has a thickness of about twenty feet in the eastern part of New York, but thins out westward and disappears before reaching lake Erie.

(4) The Genesee slates consist of black bituminous shales, very similar to the Marcellus division.

"At Kingston's Mills in Warwick we have 396 feet of soft gray shales and soapstones of the Hamilton formation, while in the valley of the Thames these strata do not measure over 250 to 290 feet, showing a rapid thickening to the northward. This augmentation of volume of essentially calcareous deposits in this direction might however be expected from the similar thickening of the Onondaga formation."

Portage-Chemung Formation

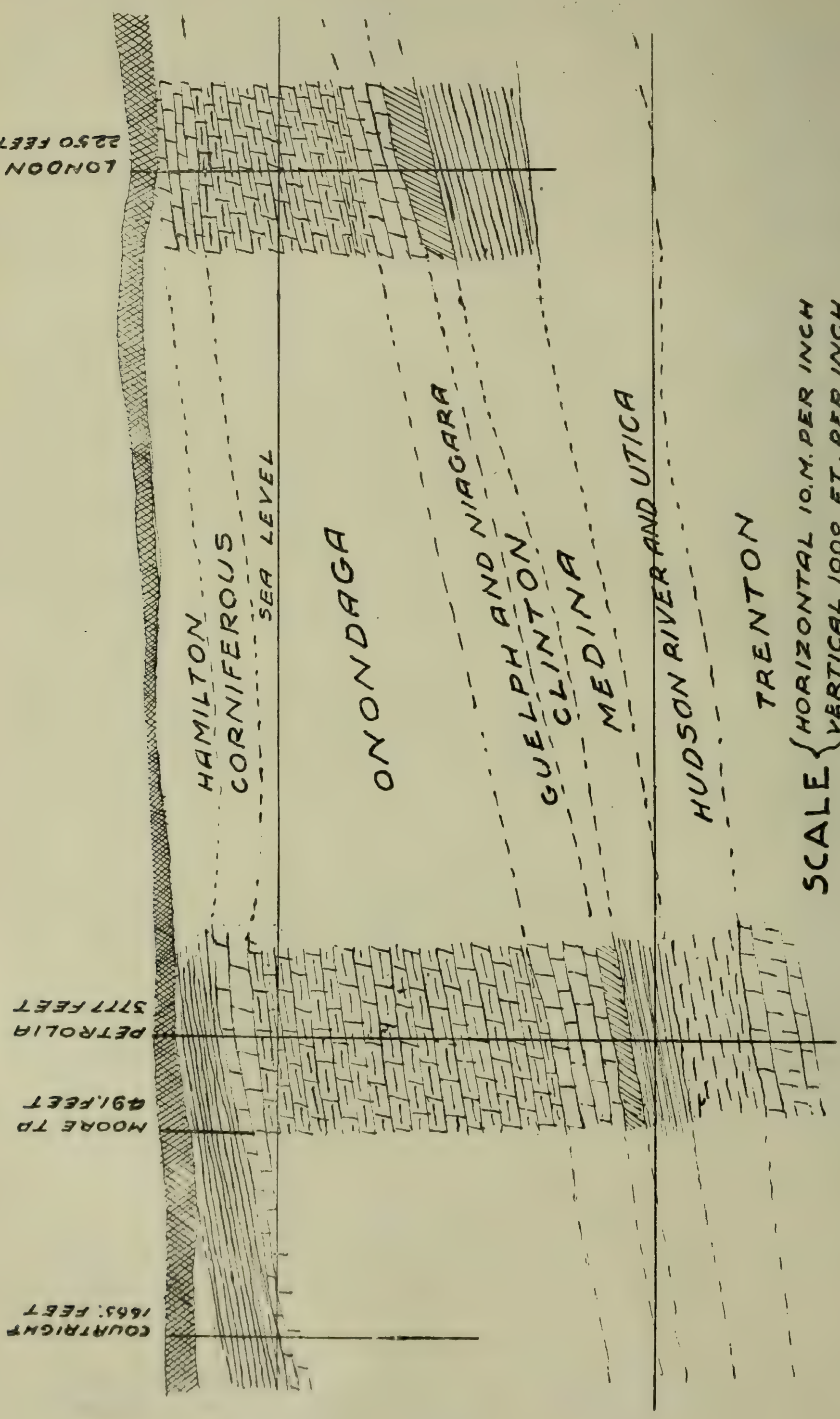
This formation is made up of dark bituminous shales holding in places large calcareous concretions and also much iron pyrites, the shales being often coated with a yellow rust of oxalate of iron. Exposures are seen at Kettle point in Bosanquet township. There is no record of these hard black shales having been met with in any boring in Enniskillen except in those unproductive ones to the north of Petrolea. A great similarity exists between the shales in the upper series of the Hamilton and the lower shales of the Portage-Chemung.

BORINGS FOR OIL AND GAS.

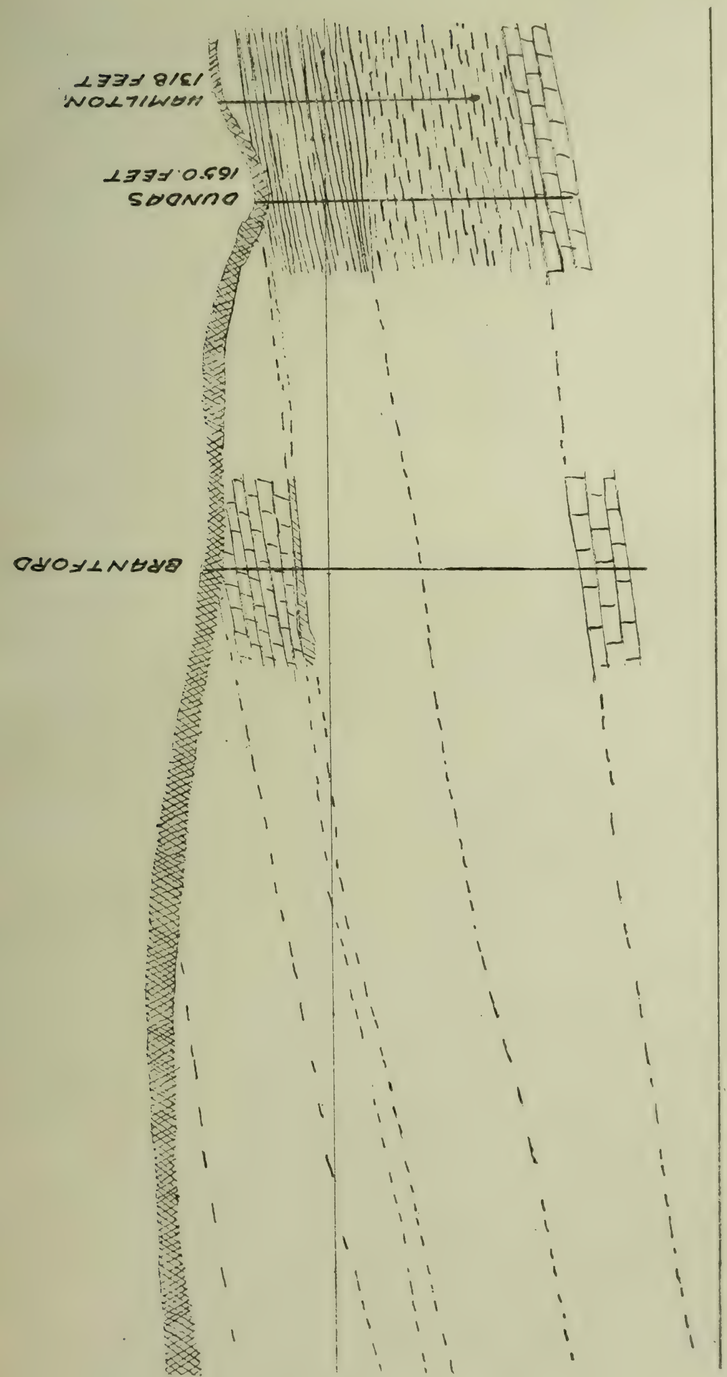
In the following pages is given a partial record of boring operations carried on in those counties of the Province which have proved productive of petroleum and natural gas.

Welland County

Welland county is the most easterly county in Ontario in which natural gas has been found in commercial quantities. This county may be said to have the largest flow of gas, and the most lasting, of any county in the Province.



Section from Hamilton to Courtright.



Section from Hamilton to Courtright
(Continued)

Gas is here found in three different formations, namely:
(1) Clinton. (2) Medina. (3) Trenton.

The gas in the Clinton is found in the first twelve feet of the formation.

In the Medina the gas is found (1) in the upper part of the red Medina sandstone, (2) in the upper white Medina sandstone, (3) and (4) in two horizons in the lower white Medina sandstone, about twenty and thirty feet below the preceding horizon in the upper white Medina.

In the Trenton the gas is found 600 feet below the top of the formation, at a depth of 2,330 feet below tide.

The old Welland field, in Humberstone and Bertie townships, has been described by Mr. Brumell,[16] and also by Mr. Coste,[17] so that it is not necessary to do more than give the logs of some of the wells by way of comparison with those of the new fields.

The following logs of wells drilled by the Provincial Natural Gas and Fuel Company give a good idea of the various strata which underlie this field and their respective thickness.

Well No. 61, Lot 2, in 4th Con. Willoughby Township; Elevation 610 feet.

Formation.	Strata.	Thickness.	Depth.	Remarks.
Drift	Clay	18 feet to	18 feet.	
Onondaga	Dolomites and shales with gypsum	202 feet to	220 feet.	
Guelph and Niagara	Gray dolomites	220 feet to	440 feet.	Salt water at 330 feet.
Niagara shales	Blue shales	50 feet to	490 feet.	
Clinton	White limestones	30 feet to	520 feet.	A little gas at 495 feet and a little salt water.
Medina	Red sandstone and shales	73 feet to	593 feet.	
	White sandstone	10 feet to	603 feet.	
	Blue shale	12 feet to	615 feet.	
	White sandstone	18 feet to	633 feet.	
	Red shales	830 feet to	1463 feet.	
Hudson River	Blue shales	717 feet to	2180 feet.	
Utica	Black shales	160 feet to	2340 feet.	
Trenton	White and gray limestones	670 feet to	3010 feet.	Gas at 2,940 feet 1,000 lb. rock pressure.
Calciferous	Gray coarse sandstone	19 feet to	3029 feet.	
Archean	White quartz	1 foot to	3030 feet.	

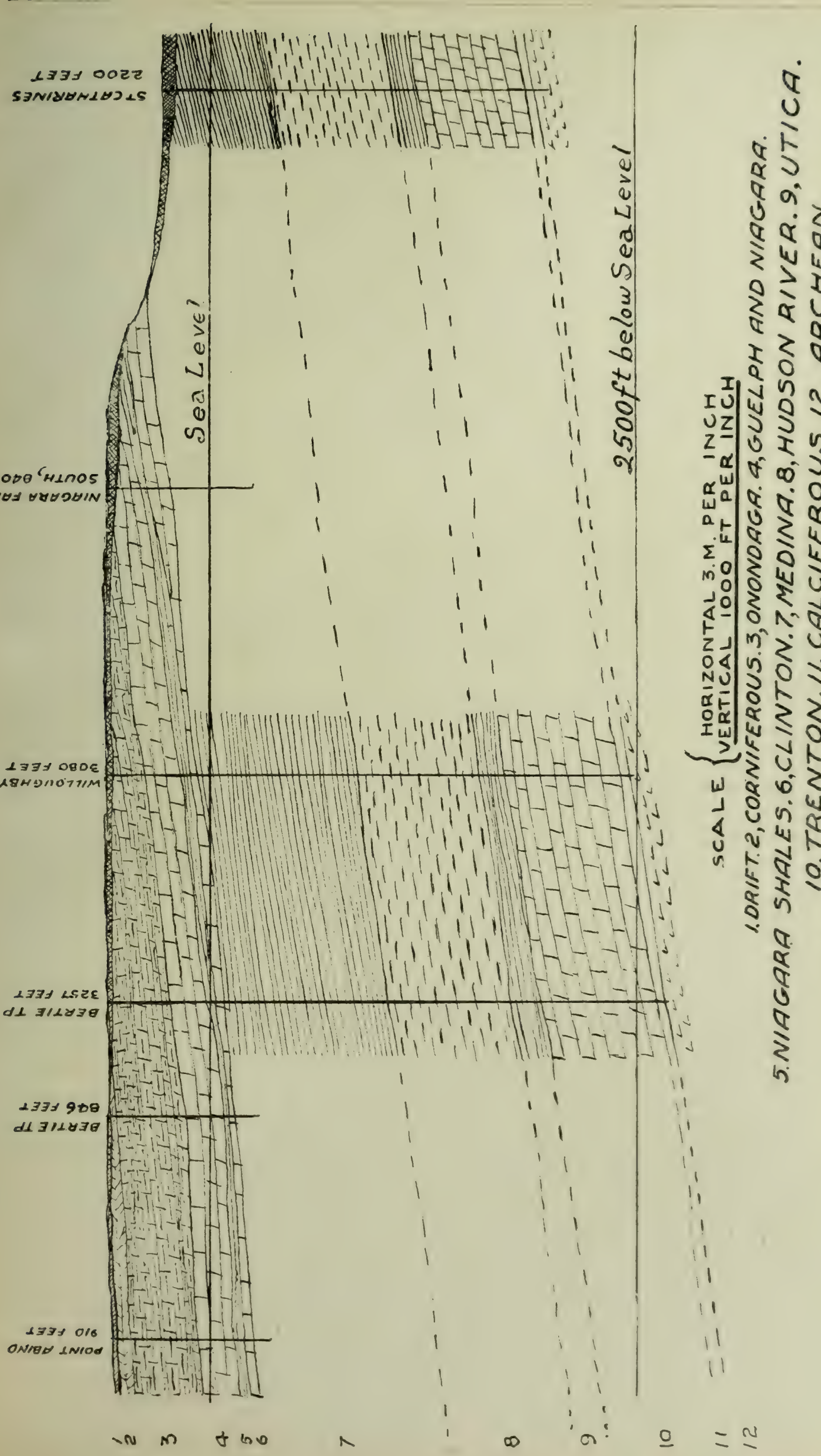
Well on Lot 6 in 15th Con. of Bertie Township; Elevation 605 feet.

Formation.	Strata.	Thickness.	Depth.	Remarks.
Drift	Clay	38 feet to	38 feet.	
Onondaga	Dolomites, gray and drab, black shale and gypsum	300 feet to	338 feet.	
Guelph and Niagara	Gray dolomite	230 feet to	568 feet.	Salt water at 470 feet.
Niagara shales	Blue shales	60 feet to	628 feet.	
Clinton	White and gray limestones	32 feet to	660 feet.	
Medina	Red sandstone	83 feet to	743 feet.	A little gas.
	Blue shale	15 feet to	758 feet.	
	White sandstone	16 feet to	774 feet.	
	Red shales	850 feet to	1624 feet.	
Hudson River	Blue shales	730 feet to	2354 feet.	
Utica	Black shales	171 feet to	2525 feet.	
Trenton	White and gray limestones	685 feet to	3210 feet.	
Calciferous	Yellowish sandstone	45 feet to	3255 feet.	A little salt water.
Archean	Mica schist	2 feet to	3257 feet.	

Well on Point Abino, Bertie Township; Elevation, 580 feet.

Formation.	Strata.	Thickness.	Depth.	Remarks.
Drift	Sand	10 feet to	10 feet.	
Corniferous	Gray limestones with flint	82 feet to	92 feet.	
Onondaga	Gray and drab dolomite, blue shales and gypsum	288 feet to	480 feet.	
Guelph and Niagara	Gray dolomites	235 feet to	715 feet.	Gas in large quantities at 500, 530 and 580 feet.
Niagara shales	Blue shales	55 feet to	770 feet.	
Clinton	White limestone	30 feet to	800 feet.	
Medina	Red sandstone	80 feet to	880 feet.	
	Blue shale	13 feet to	893 feet.	
	White sandstone	17 feet to	910 feet.	Gas at 902 feet.

16 Rep. Geol. Sur. Can., 1890-1, page 330. 17 Journal Can. Min. Inst., Vol. III., p. 77.



SECTION FROM POINT ABINO TO ST CATHARINES

From the information derived from the logs of a great number of wells drilled in this county Mr. Coste points out the following features:[18]

"1. The strata dip to the south and southeast uniformly at the rate of about 35 feet to the mile except for a small synclinal (about one mile wide and 30 feet deep) the axis of which is about one mile north of No. 22 well at Point Abino.

"2. Salt water was struck in every well in large quantities towards the middle of the Guelph and Niagara formation. A little salt water is also found in the Clinton, in the White Medina gas rock and in the Calciferous, at No. 14, but in none of these formations below the Guelph and Niagara is there anything like a continuous body of salt water, which on the contrary lies there in disconnected small bodies of water.

"3. Besides being found in the strata indicated in the above logs gas was also found in some other wells in large quantity, 5 feet in the Clinton limestone, 10 feet in the red Medina sandstone and in the upper white sandstone of the Medina. Some amber-green color oil of a gravity of 42½ degrees Beaumé was also found in the last few feet of the lower white Medina sandstone at wells Nos. 20, 28 and 62. The gas in that sandstone is generally found 3 feet in from the top of it, but often also another vein is found 9 to 10 feet in."

The Crowland gas field occupies an area of two miles by one and one-half miles, about the middle of the township of Crowland.

The well on lot 12 concession six, township of Crowland is quite typical for the field.

Formation.	Strata.	Thickness.	Depth.	Remarks.
Onondaga	Surface	120 feet to	120 feet.	
	Dolomites and shales	120 feet to	240 feet.	
Guelph and Niagara	Gray dolomites	233 feet to	473 feet	Casing at 475 feet.
Niagara shales	Blue shales	55 feet to	528 feet	
Clinton	White limestone	30 feet to	558 feet	Gas at 538 feet.
Medina	Red sandstone and shales	61 feet to	618 feet.	
	White sandstone	12 feet to	631 feet.	
	Blue shales	11 feet to	642 feet.	
	White sandstone	18 feet to	660 feet.	

This field is operated chiefly by The Provincial Natural Gas and Fuel Company. The gas is piped to Niagara Falls.

Another new field that was opened in 1903 is the Winger field in Wainfleet township. This field comprises practically the fourth and fifth concessions between lots 25 and 31, and has been surrounded with dry holes, showing it to be simply a pool. The gas was first utilized from this field in January 1904, being piped into the mains in the old Welland field.

Log of well No. 4, on lot 31, concession 5, Wainfleet township:

	Feet		Feet
Surface	0—144		
Limestone and shale	144—315,	Onondaga	171
Gray dolomite	315—475,	Guelph and Niagara	160
Blue shales	475—520,	Niagara shales	45
White limestone	520—555,	Clinton	35
Red sandstone	555—615,	Medina	60
Gray shales	615—640,	"	25
White sandstone	640—662,	"	22

Cased off water at 490 feet. Gas found at 640 feet in the white Medina sandstone, with twelve feet of gas sand, and at a rock pressure of 260 lb. Average depth of wells 665 feet.

There are twelve producing wells in this field, eight being owned by the Provincial Natural Gas and Fuel Company, and four by the Niagara Peninsula Power and Gas Company, who are piping the gas to St. Catharines, where it is sold to the St. Catharines and Niagara Power and Fuel Company for distribution through the city. Piping to St. Catharines has not yet been completed.

[18] Journal Can. Min. Inst., Vol. III., p. 77.

On a well sunk on lot 6, first concession, township of Wainfleet, the records show the following formations:

	Feet	
Gray dolomites, shales and gypsum	390	Onondaga
Gray dolomite	240	Guelph and Niagara
Blue shale	55	Niagara shales
Dolomite	30	Clinton
Sandstone, red	45	Medina
Shale, red and blue	40	Medina
Sandstone, white	20	Medina

Gas having a flow of 400,000 cubic feet was obtained at 685 feet at the summit of the Clinton. No gas was found here in the Medina.

It has previously been proved that the strata in the old Welland field dip uniformly to the south and southeast at a rate of thirty-five feet to the mile. By a comparison of the last two logs, it is seen that there is a similar dip in the vicinity of the Winger field.

Haldimand County

Explorations for gas have been carried westward from the Welland county fields to this county with fairly good results. In 1902, there were nine producing wells in the vicinity of Dunnville. The Attercliffe field, about five miles northeast of Dunnville in the northern parts of the townships of Moulton and Canborough, is the most important in the county, although several producing wells have been put down outside this field. The Dominion Natural Gas Company have thirty-four wells in this field and five wells in other parts of the county. The Citizens' Natural Gas Company of Dunnville have nine producing wells in this field.

Log of well No. 3 on lot 18 in the second concession from Canborough.

	Feet	
Surface (clay)	100	Upper shales, probably Onondaga
Shale and rock	318	Guelph and Niagara
Gray shale	45	Niagara shales
Dolomite	23	Clinton
Sandstone, red	48	Medina
Blue shale	48	"
White Medina	10	"
Red shales	depth of 26	
	618	

The gas is found in the white Medina at a depth of 582 feet, with a flow of 12,000 to 13,000 cubic feet per day.

Log of well No. 2 on the Mansell McCallum farm one-half mile south of Darling road station on the Wabash railway, Canborough township.

	Feet	Feet	Feet	
Surface	0—	56		
Limestone, shale and gypsum	56—	346	290	Onondaga
Gray dolomite	346—	506	140	Guelph and Niagara
Blue shale	506—	546	40	Niagara shales
Dolomite	546—	564	33	Clinton
Gray shale	564—	579		Clinton
Sandstone, red	579—	619	40	Medina
Gray shales	619—	649	30	"
Sandstone, white	649—	669	20	"
Red shales	6 9—	725	20	"

Gas in white Medina at 665 feet having a flow of 72,000 feet per day. Water was found in the Onondaga and Niagara.

Log of well No. 1 on the farm of K. S. Robbins, one and one-half miles west of McCallum's well, North Cayuga township.

	Feet	Feet	Feet	
Clay	0—	58		
Limestone and shale	58—	358	300	Onondaga
Gray dolomite	358—	518	160	Guelph and Niagara
Blue shales	518—	558	40	Niagara shales
Dolomite	558—	573	25	Clinton
Gray shales	573—	583		Clinton
Sandstone, red	583—	623	40	Medina
Gray shales	623—	663	40	"
Sandstone, white	663—	680	17	"
Red shale	680—	790	110	"

Gas is found at 667 feet in the white Medina sandstone, having a flow of 60,000 feet per day.

A comparison of the logs of the last four wells shows the several strata to have a respective thickness in feet as follows:

	No. 1	No. 2	No. 3	No. 4
Clay	58	56	100	144
Limestone and shales	300	290	318	171
Gray dolomite	160	140	...	160
Blue shales	40	40	45	45
Dolomite / Gray shales	25	33	23	35
Sandstone, red	40	40	48	60
Gray shales	40	30	48	25
Sandstone, white	17	20	10	22
Red shales	110	56	26	..

All of the wells were put down to the red shales and there left unfinished.

In comparing the logs of the three wells given in Haldimand county, and the log of well on lot 31, concession 5, Wainfleet township, all being practically on a line running east and west, and the wells on the extremities of this line being sixteen miles apart, we find the depth of the white Medina sandstone in which the gas is found at depths of 667, 656, 582 and 640 feet respectively from west to east, or 51, 53, 6 and 60 feet respectively below tide. This shows that between wells 2 and 4 there is a slight anticline. Well No. 3 is in the Attercliffe field. This field is therefore on an anticline having a total height of about 60 to 65 feet. Sufficient logs were not obtained to determine its axis or dip.

Some wells have been drilled in the town of Dunnville, gas being obtained in small quantity in nearly all. One well put down by citizens in the town averaged a pressure of 100 lb. for seven months. Gas is found here in the White Medina sandstone at a depth of 800 feet.

The strata in this county dip uniformly to the south thirty-one feet to the mile.

Gas is piped by the Dominion Natural Gas Company from their wells in Haldimand to Hamilton and Dundas, a pressure of 60 lb. being obtained at Dundas. The main pipe line is an 8-inch line running from Canfield in Cayuga township through to Seneca township, and the small towns of Blackheath, Binbrook and Rymal to Hamilton. Another small line carries it from Hamilton to Dundas. Smaller pipe lines from the company's wells in Cayuga and Canborough supply the main line. Gas is also piped to Dunnville by both the Dominion and Citizens' Natural Gas Companies.

Brant County

Explorations for gas in this county were carried on in 1888, and two wells were drilled, one being put down to the Trenton. The boring, however, as far as has been recorded, was unsuccessful. In 1903 drilling for gas was again undertaken in the city of Brantford, and six or seven wells were put down, four being on the Cockshutt property. A strong flow of gas was obtained, and used in the furnaces of the Cockshutt manufacturing works. The pressure after some time began to lessen until the supply was not sufficient to keep the furnaces going. It was then found that oil had oozed into two of the wells. These are now producing about eighteen barrels per month. In one well drilled by the Cockshutts a pocket of gas was struck which at first yielded 775,000 cubit feet per day, diminishing to 12,000 to 15,000 feet per day.

Log of Cockshutt well No. 3:

	Feet	
Surface		
Sandy loam	7	
Wash gravel	3	
Clay	40	
Quicksand	21	
Hard pan	11	
Limestone, &c	283	Guelph and Niagara
Black shales	45	Niagara shales
Dolomite	12	Clinton sand
Red shales	45	Medina
Gray shales	45	"
Sandstone	20	"
Red shales	88	"

Gas and oil are found in the Medina sandstone at a depth of 512 feet.

Record of well drilled by Gould, Shapley and Muir Co., on Wellington street, Brantford:

	Feet		Feet.
Surface	0—61		
Limestone, etc	61—360	Guelph and Niagara	299
Black shales	360—405	Niagara shales	45
Dolomite	405—425	Clinton	20
Sandstone, red	425—460	Medina	65
Blue shales	460—490	"	30
Sand rock	490—505	"	15
Sandstone, white	505—515	"	10
Red shales	515—670	"	155

Gas was struck at a depth of 610 feet, and according to the record obtained from the driller, in the Medina red shales, 100 feet below the horizon in which the gas is found in other wells in this district. The rock pressure at first was 265 lb. The well is now flowing 15,000 cubic feet per day. It is altogether probable that as the gas pressure decreases in this well oil will begin to come in.

The discovery of gas and oil at Bow Park Farm, two miles southeast of Brantford is described in the Thirteenth Report of the Bureau of Mines. Development work has been steadily going on since that time and ten wells in all sunk, one of them being put down to the Trenton.

Log of well No. 4 on Bow Park Farm:

	Feet		Feet.
Surface	0—72		
Limestone, etc	72—365	Onondaga, Guelph and Niagara	293
Black shales	365—415	Niagara shales	50
Dolomite	415—430	Clinton	15
Red shales	430—475	Medina	45
Blue shale	475—505	"	30
Gray sand (hard)	505—525	"	20
Sandstone, white	525—532	"	7
Red shales	532—624	"	92

First gas struck at 420 feet in the Clinton.
Second gas struck at 530 feet in the Medina white sandstone.
Oil struck at 542 feet in the Medina red shales.

The logs of the wells drilled on this farm are very similar, the greatest variation being in the thickness of the white Medina sandstone.

Logs of wells No. 6, 7, 8 and 9 on Bow Park farm:

	No. 6 ft.	No. 7 ft.	No. 8 ft.	No ft.
Surface	87	45	91	97
Onondaga, Guelph and Niagara limestone	292	276	300	290
Niagara black shales	45	45	45	45
Clinton dolomite	20	15	23	23
Medina red shales	30	30	31	35
Medina blue shales	30	35	30	35
Medina gray sand	20	25	30	15
Medina sandstone, white	13	10	....	11
Medina red shales	111	135	203	80
	650	616	753	630

In No. 6 gas was struck at 430 feet in the Clinton, and at 538 feet in the Medina white sandstone. Oil was struck at 590 feet or 63 feet in the Medina red shales.

In No. 7 a very small flow of gas was obtained at 479 feet in the Clinton.

In No. 8 a flow of gas was obtained at 439 feet in the Clinton. From the log it is seen that the Medina white sandstone is entirely lacking in this well, which will account for no gas being found below the Clinton in the depth drilled.

In No. 9 gas was found at 436 feet in the Clinton sandstone, and at 549 feet in the Medina white sandstone. Oil came in 60 days after the well was drilled.

This field is similar to the Dunnville and Attercliffe field in that the gas is obtained from the Clinton and white Medina sandstone. The chief supply of gas comes from the latter, the top of which is at an average depth of 530 feet or about 150 feet

of an elevation above tide. The top of the white Medina sandstone in the gas district of Haldimand county is found at an elevation of about 45 feet below tide. There is therefore a difference in elevation of about 195 feet, or a uniform dip of the white Medina sandstone to the south of nine to ten feet per mile.

The Trenton formation is struck on Bow Park Farm at a depth of 1,930 feet or an elevation of 1,250 feet below tide. The Trenton is encountered in Welland county at an elevation of about 1,750 feet or 500 feet lower than at Brantford, showing the Trenton also to have a south and southeasterly dip, with some of the lower strata increasing in thickness in a southeasterly direction.

The gas from the wells at Bow Park Farm has been piped to Brantford and leased to the Imperial Natural Gas Company, who supply the city.

Two or three of the wells have been shot, but the flow did not appear to be increased.

The Provincial Natural Gas Company drilled three holes northeast of Bow Park but nothing was struck.

Norfolk County

Following is the record of a well drilled at Port Rowan in the county of Norfolk:

Depth.	Formation.	Color.
0— 300		Surface Clay.
300— 363	Corniferous	Gray limestone.
363— 440	"	Grayish-blue limestone.
440— 470	"	Dark brown.
470— 564	"	Bluish gray.
564— 585	Corniferous or Oriskany	White and blue granular limestone.
585—1,020	Onondaga	Grayish-blue dolomite.
1,020—1,310	Niagara	White sugary limestone.
1,310—1,320	Clinton	Drab and argillaceous limestone.
1,320—1,460	Medina	Red and blue sandstone.

Elgin County

Drilling for oil was first begun in this county about forty years ago. About eight years ago a deep well was drilled at St. Thomas to a depth of 3,030 feet. A very little gas was found in the Medina, but salt water was encountered and the well was of no importance. About the same time drilling was begun in the township of Dunwich about 20 miles west of St. Thomas. This is the Dutton field and is about five miles south of the village of that name.

The field comprises in all about 400 acres, and 154 wells have been drilled in it, 68 wells by the Elginfield Oil & Gas Developing Co., 73 wells by the Beaver Oil Co., and 13 by the Talbot Oil Co. The oil is found in the Corniferous at a depth in it of 160 to 175 feet. The best wells are obtained when the Corniferous is struck 245 to 250 feet from the surface.

Log of a well of the Elginfield Oil & Gas Co.:

Surface	200 feet	
Black shales	6-7 feet	Hamilton
Hard pan / Blue clay	25 feet	Hamilton
Limestone	170 feet	—Corniferous
Total depth	402 feet	

Oil was struck at a depth of 160 feet in the Corniferous, and 9 feet of oil rock passed through.

Log of wells drilled by the Beaver Oil Co.:

Surface	228 feet	
Lime (gray shales)	25 "	—Hamilton
Limestone	187 "	—Corniferous.
Total depth	440 feet.	

Oil found at 175 feet in the Corniferous.

	Feet.	
Surface	208	
Lime (shales)	27	Hamilton.
Limestone	172	Corniferous.
Total depth	40	

Average of 16-18 feet of "cuttings" (oil rocks.)

Some wells have no shale overlying the Corniferous.

	Feet	
Surface	183	
Limestone	167	Corniferous.

The best wells in the field are found where there is 25 to 30 feet of shale overlying the Corniferous lime. It would thus appear that there is a series of auxiliary anticlines running through the field.

The wells in the Dutton field are different from those in the Petrolia field, although oil in both fields is found in the Corniferous. In the latter field oil is struck 65 to 70 feet below the surface of the Corniferous, while in the former oil is found from 160 to 170 feet in it. The wells are similar to the Petrolia wells in that they are small but steady producers.

All the wells are shot with fifteen quarts of nitro-glycerine.

Log of a well twenty miles west of Dutton at Clearville:

	Feet.	
Surface	167	
Soap (shales)	183	Hamilton.
Limestone	165	Corniferous.

Salt water was struck.

In the eastern part of this county a few wells were drilled in 1903 which produced some oil.

Log of well near Aylmer, township of Malahide:

Surface clay, sand and gravel	247 feet
Corniferous lime	169 "

A little surface oil was struck at 247 feet, and also a little at 278 feet. At 386 feet, or 139 feet in the Corniferous, oil was found which yielded three barrels per day. This is a very light oil with a gravity of 41 degrees Baumé.

Kent County

Many wells have been drilled in this county in search of both gas and oil, principally in the years following the discovery of oil at Petrolia and Oil Springs, also in latter times in search of gas, so far unsuccessfully except for small quantities.

The Bothwell field is probably the most steady producer of oil of any field in the county. It is situated in the northern part of Zone township between the Grand Trunk Railway and the Thames river, about two and one-half miles west of the village of Bothwell. The Walker Gas and Oil Company, Windsor, and Fairbanks and Carman, Petrolia, are the principal operators. The former company have sunk about ninety wells having an average depth of 600 feet. These wells produce 15,000 barrels of oil a year, and the production is said not to depreciate more than two per cent. each year. To offset this four new wells are put down each year.

Well at Bothwell:

	Feet.		Feet.
Surface	155		
Soapstone	31	Hamilton	67
Shale, black	4		
Soapstone	32		
Limestone	148	Corniferous	

The total number of producing wells is from 250 to 300, but new ones are continually being sunk. The yield of oil is from 5,000 to 6,000 barrels a month for the whole oil field.

Log of well at Bothwell:

	Depth. Feet.		Feet
Quicksand	15— 15	Surface	167
Clay	45— 60		
Running Gravel	85—145		
Clay	10—155		
Quicksand	5—160		
Hard pan	7—167		
Middle lime	10—177	Hamilton	36
Soapstone	16—193		
Lime	8—201		
Lower lime	178—381	Corniferous.	

Some water and oil obtained at 210 feet; began to show oil at from 345 to 350 feet, but from 365 to 376 feet the limestone is quite coarse and oil washes out. The well was shot with sixteen quarts of nitro-glycerine from 365 to 376 feet. Oil is therefore found in the Corniferous at a depth of 188 feet. The Hamilton formation in this field has been greatly eroded, being about 200 feet less in thickness than at Petrolia or Thamesville.

At Thamesville about seven miles west of the Bothwell field a number of wells have been put down, yielding oil in some cases. Dr. Hunt gives the log of a well at this place as follows:

	Feet.	
Clay	60	
Gray shale, etc.	240	Hamilton.
Gray limestone	32	Corniferous.

Oil was found at sixteen feet in the Corniferous.

Another well drilled recently by Messrs. Fairbank and Company of Petrolia gives the log as follows:

	Feet.		Feet.
Sand	4— 4	Surface	69
Blue clay	50— 54		
Stones	15— 69		
Black shale	10— 79	Hamilton	237
Top rock	40—119		
Soap	130—249		
Middle lime	14—263		
Soap	33—296		
Lower lime	146—442	Corniferous.	

Oil and gas were found at depths of 356 and 427 feet, or at 60 and 131 feet in the Corniferous. This well is almost identical with wells drilled in the Petrolia field with the exception of a smaller thickness of surface.

On lot 19 in the fifth concession of Dover township near Chatham a well has been put down to a depth of 500 feet.

	Feet.		Feet.
Sand	15		
Clay	50		
Shale	60	Hamilton	270
Top rock	40		
Soap	120		
Middle lime	15		
Lower soap	35		
Lower lime	105	Corniferous	167
White sand rock	45		
Dark sand rock	17		

Salt water was struck at 350 and 400 feet respectively.

19 Geol. Survey of Canada 1863, p. 247.

Another well which Mr. H. P. H. Brumell describes[20] was drilled one mile northwest of the Grand Trunk Railway station at Chatham:

	Feet.	
Surface clay	60	
Shale, black	118	
Soapstone	200	Hamilton.
Limestone (middle lime)	18	Hamilton.
Soapstone	37	Hamilton.
Limestone	567	Corniferous.

Part of this black shale is likely to belong to the Portage-Chemung. The Hamilton averages about 30 feet in thickness, and the upper black shales of the Hamilton and lower shales of the Portage-Chemung are very similar. The record given shows the limestone below the Hamilton to have a thickness of 567 feet. This is a greater thickness than has been found in the Corniferous. The lower layers are therefore in all probability a dolomite belonging to the Onondaga.

Oil was struck in a well on lot 18 in the twelfth concession of Raleigh township in November of 1902. This well was called the "Gurd gusher" and produced during its flowing period about 1,000 barrels per day. Many wells were drilled in the vicinity, but with little success. At the present time there is nothing being done in the field. The "gusher" ceased to flow, and pumping has been stopped.

This field is described by Prof. Miller,[21] from whose report the following log has been taken. The well is on lot 19, concession 14, township of Raleigh.

	Feet.		Feet.
Boulder clay	184		
Shale ....to	205		
Limestone (argillaceous) ....to	211	Hamilton	94½
Shale ....to	240	Hamilton	
Limestone ....to	246	Hamilton	
Shale ....to	247	Hamilton	
Limestone (middle lime) ....to	249	Hamilton	
Shale ....to	278½	Hamilton	
Limestones, very slightly argillaceous ....to	511	Corniferous	232½

The last is called the "big lime" or "lower lime."

The Wheatley field in the vicinity of Wheatley village in Romney township is a small producer. The United Gas and Oil Company have four wells on lot 11 in the second concession, which yield an average of ten barrels per day. These wells are sunk to a depth of 1,298 feet. The water is shut off at a depth of 595 feet in the Niagara. About 400 feet of salt, called by the drillers the "big salt" is also obtained. A very hard gray limestone overlies the oil strata. The oil is found in the Guelph formation.

Lambton County

This county has been for many years the foremost and was for some time the only oil producing district in the Dominion. The Petrolia and Oil Springs fields have been fully described by Mr. H. P. H. Brumell,[22] consequently the writer will confine himself to a brief mention of the more recent operations in the county.

Mr. Brumell writes as follows:

"The oil of Lambton county is, in the main, obtained from two distinct pools known as the Oil Springs and Petrolia fields, both in the township of Enniskillen. The larger of the two—the Petrolia field—with an approximate area of twenty-six square miles, extends W. N. W. about nine miles and E. S. E about four miles from the village of Petrolia; while the Oil Springs field covers about two square miles and includes the south eastern part of the village of Oil Springs."

A new field can now be added to these two, which bids fair to become a good producer. This is the Moore field, and comprises approximately lots 1 to 5 in the ninth.

20 G. S. C., 1890-91 Report, p. 73 Q

21 Thirteenth Rep. Bureau of Mines, 1903, page 40.

22 G.S.C., 1890-91, page 61 Q.

tenth and eleventh concessions of the township of Moore. The best wells are located on lots 3 and 4 in the ninth and tenth concessions. This field was opened up by the Moore Oil and Gas Company in July, 1904, and is about four miles west of Petrolia.

Log of the Davis well drilled by the Moore Oil and Gas Company on lot 3 in the tenth concession of Moore township near the old Sarnia plank road:

	Feet.		Feet.
Surface	148		
Top rock (upper lime)	45	Hamilton	232
Shale (upper soap)	125		
Limestone (middle lime)	15		
Shale (lower soap)	47		
Limestone (lower lime)	111	Corniferous.	
Total depth	491		

Supply of gas struck at 400 feet. Oil struck at 445 to 450 feet at a depth of 65 to 70 feet in the Corniferous.

This well, which was the second well in the field drilled, started out with a production of 100 barrels per day.

Log of well drilled by Fairbanks and Carman:

	Feet.		Feet.
Surface	143		
Top rock	48	Hamilton	240
Soap	130		
Middle lime	15		
Soap	42		
Streak of lime	3		
Soap	2		
Lower lime	68	Corniferous.	

The Corniferous formation was encountered at a depth of 384 feet, and oil found at 395 feet and 410 feet.

Details of the Corniferous formation in the above well are as follows:

Feet.	
395	Crystalline limestone.
400	Gray.
402½	Gray.
405	Gray, no oil.
407½	Soft.
410	Rock well browned up with oil.
412	Gray.
417½	Crystalline.
422½	Soft, browner, more crystalline.
425	Gray, oil came in.
427½	Hard.
430	Brown and sandier.
437½	Crystalline.

The Moore field is quite clearly defined by a black shale which is found south, east and west of the field at depths of 127, 100 and 132 feet respectively. In the field the top rock is at a depth of 147 to 154 feet. No producing well has been found where the black shale overlies the top rock. The "lower lime" in the wells on the edge of the field is met at a greater depth than in the middle of the field, proving quite conclusively the presence of an eroded anticline. This black shale is in all probability the upper strata of the Hamilton, which at Petrolia assumes a thickness of 296 feet.

North of the field, no shale is found overlying the "top rock" for some distance, and a few producing wells have been located. It has been thought that the oil belt ran in a direction northwest by southeast, but in this field it runs rather in a southwesterly by northeasterly direction and quite irregularly, except that as the shale is neared the wells diminish in production.

The oil is found in two horizons from fifteen to twenty feet apart of about eight to ten feet thickness. The wells are connected as shown by the fact that some wells drilled the width of 100 acres from a producing well have reduced the flow of the latter. From fifteen to twenty wells have begun pumping from 40 to 100 barrels per day. In March, at the time of the writer's visit to this field, there were twenty drilling rigs at work.

All the wells are shot with from thirty to forty-five quarts of nitro-glycerine.

In this field there is also considerable gas which is used as fuel for pumping and drilling on most of the properties.

Mr. Brumell writes regarding the Petrolia wells as follows:[23]

"The oil horizon at Petrolia lies at a depth of from 450 to 480 feet beneath the surface of the main part of the town, the oil being pumped in all instances from what is known as the 'lower vein' at a point about 65 feet in the Corniferous limestone. The following record may be taken as typical of the wells sunk in the Petrolia field."

Well sunk near the Imperial Refinery, Petrolia:

	Feet.		Feet.
Surface	104		
Limestone (upper lime)	40	Hamilton	228
Shale (upper soapstone)	130		
Limestone (middle lime)	15		
Shale (lower soap)	43		
Limestone (lower lime)	68	Corniferous	133
Limestone, soft	40		
Limestone, gray	25		

Following is the log of a well that was sunk at Petrolia to the Trenton line:

Carman well No. 1, lot 11, concession 11, Enniskillen, Lambton county, Ontario, R. I. Bradley estate, Elev. A. T. 667 feet:

			Feet.	Feet.
HAMILTON		Surface blue clay	90	90
		Streaks lime and shale	240	330
CORNIFEROUS		Corniferous	190	520
ONONDAGA		Streaks brown, gray and black dolomite	690	1,210
	SALINA.	Salt	65	1,275
		Dolomite	20	1,295
		Salt and thin streaks dolomite	140	1,435
		Dolomite	30	1,465
		Salt	90	1,555
		Salt with light and dark streaks dolomite	50	1,605
		Salt	25	1,630
		Gray dolomite lime	10	1,640
		Salt	67	1,707
		Streaks dolomite and salt	40	1,747
		Salt	138	1,885
		Gray dolomitic lime and shale	130	2,015
		Salt	90	2,105
CLINTON		Guelph and Niagara dolomitic lime	275	2,380
		Niagara shale (red and dark)	60	2,440
		Clinton	90	2,530
MEDINA		Red Medina	275	2,805
UTICA		Hudson River shales (light)	205	3,010
		Utica (dark)	165	3,175
TRENTON		Trenton	170	3,345
		Bird's Eye	115	3,460 602
		Chazy	317	3,777

Thirteen-inch conductor, 98 feet; $7\frac{5}{8}$-inch casing, 186 feet; $6\frac{1}{4}$-inch casing, 1,015 feet.

In the Oil Springs field, oil is found at a depth of about 370 feet or 60 to 65 feet below the summit of the Corniferous. The shallowness of the wells as compared with those at Petrolia is due to the thinner mantle of surface drift, and also to a diminished thickness of the Hamilton formation, as shown by the following log:

	Feet.		Feet.
Surface	60		
Limestone (upper lime)	35	Hamilton	170
Shale (upper soapstone)	101		
Limestone (middle lime)	27		
Shale (lower soap)	17		
Limestone (lower lime)	130	Corniferous.	

Another well drilled at Oil Springs gave the following log:

	Feet.		Feet.
Blue clay	58		
Top rock	55	Hamilton	209
Soap	109		
Middle lime	15		
Soap	30		
Lower lime	131	Corniferous.	

[23] G.S.C. Report, 1890-91, page 61 Q.

Another field in the southern part of the county in Euphemia township is a small producer. Very little is being done here at present, but a little oil is being pumped.

The log of a well in this township gives:

	Feet.
Surface..	53
Hamilton	224
Corniferous	93

Oil is found in the Corniferous at depths of 90 to 100 feet.

According to Mr. Coste[24] oil has also been found in the Oriskany sandstone, which underlies the Corniferous, in this field. This is the only record we have of oil having been found in this formation.

Log of well drilled by Fairbanks and Carman in Euphemia township:

	Feet.		Feet.
Surface clay	48		
Top rock	50	Hamilton	218
Soap	130		
Middle lime	20		
Soap	18		
Lower lime	120	Corniferous.	

Oil is obtained at about 100 feet in the "lower lime."

Log of well drilled in the township of Dawn:

	Feet.	
Surface clay..	38	
Streaked with lime..................................	20	....Hamilton 199 feet.
Soap..	128	
Middle lime	20	
Soap..	25	
Lime..	4	
Soap..	2	
Lower lime	100	........Corniferous.

Oil was struck at a depth of 87 feet in the Corniferous.

Essex County

Explorations in this county until very recently have been mainly in search of natural gas, which was first proved to exist in this county in large quantities in January, 1889. Many wells have been drilled in various parts of the county, chiefly in the district between Kingsville and Leamington and in Colchester township.

Probably the largest flow of gas obtained from any well was from Coste well No 1 in the northwest corner of lot 7 in the first concession of the township of Gosfield, which is thus described by Mr. Coste:[25]

Soil..	0 feet to 5 feet.	
Drift, gray sand..............................	5 " 120 "	
Brown and gray dolomitic limestones, with gypsum and with white and black flint.	120 " 500 "	....Onondaga 900 feet.
Gray blue and shaly dolomites and drab brown dolomites with a good deal of gypsum	500 " 860 "	
Dark brown dolomites and gypsum (with gypsum bed from 970 to 985)............	860 " 1020 "	
Gray blue crystalline vesicular dolomite....	1020 " 1031 "	......Guelph 11 feet.

A little gas was got at 910 feet and 930 feet, but a large quantity at 1,020 feet or at 362 feet below tide. The flow of gas from this well measured, after being first brought in, 10,000,000 cubic feet per day.

A complete log of the measures underlying this county was obtained from a well drilled by the Provincial Natural Gas and Fuel Company on lot 64 in the first concession of the township of Colchester South; elevation 648 feet.

[24] Journal Can. Min. Inst., Vol. VI., page 110.
[25] Journal Can. Min. Inst., Vol. III., p. 70.

Formation.	Strata.	Thickness.	Depth.	Remarks.
Drift	Sand	20 feet to	20 feet.	
"	Quicksand	90 "	110 "	
Onondaga	Gray and brown dolomitic limestone with flint and gypsum	67 "	177 "	
"	White fine sharp sand	10 "	187 "	
"	White, gray and brown dolomites with white and black flint and with gypsum	203 "	390 "	
"	Gray, blue and brown dolomites (mostly shaly with a good deal of gypsum), shaly group	370 "	760 "	
Guelph and Niagara 215 feet	Blue, white, gray and brown dolomite, quite crystalline and very porous.	215 "	1,125 "	Salt; black salt water at 910 feet and again at 1,010 feet.
Clinton 155 feet	White and white blue limestone	155 "	1,280 "	More salt water at 1 232 feet
Medina 285 feet	Gray blue shale	7 "	1,287 "	
"	Gray blue limestone	5 "	1,292 "	
"	Green shales	8 "	1,300 "	
"	Red pink shales	5 "	1,305 "	
"	Gray blue unctuous shales	88 "	1,393 "	
"	Gray blue and white sandy limestones	62 "	1,455 "	
"	Red pink shales	110 "	1,565 "	
Hudson River	Gray blue lime shales with shells of lime	350 "	1,915 "	
Utica	Brown and black shales	235 "	2,150 "	
Trenton	White and dark gray limestones	270 "	2,420 "	A little gas and oil at 2,150 feet.

Mr. Coste points out[24] the principal features revealed by the drilling in this county to be as follows:

"1st. In the south and southeast part of the county of Essex along lake Erie the first stratum met with under a heavy sand drift is the Onondaga and not the Corniferous, as it was supposed and as shown on the geological maps.

"2nd. Between the Coste well No. 1 and well No. 3 of the Ontario Natural Gas Company, in a distance of three-quarters of a mile, there is a dip of 80 feet. This, as shown by the logs of other wells between these two, is due to a fault in the strata running in a direction W. N. W. and E. S. E., and passing only a little to the north of Coste well No. 1. The logs of other wells to the west of Coste well No. 1 have also revealed another fault running a short distance west of that well in a direction at right angles to the fault above mentioned.

"3rd. An extensive bed of gypsum 10 to 20 feet thick has been regularly found in the lower part of the Onondaga formation. This bed underlies the greater part of the county of Essex.

"4th. Oil and gas * * * are known to exist in many parts of the country and in a number of different strata.

"5th. Large quantities of salt water are always found in Essex county in the Guelph, and Niagara and in the Clinton.

"6th. The Oriskany sandstone is well developed in the western and northern parts of the county, but is missing in same parts of it as shown by the record of well No. 1 of the Union Gas Co."

Drilling operations are at the present time in Essex county confined chiefly to Mersea township in an area about six miles east of the most productive gas wells at Ruthven. As stated before, oil was found near Leamington in 1902, but the first few months of 1905 has witnessed the bringing in of some large producers in this belt.

As far as yet discovered, the productive area extends from concessions one to nine in the township of Mersea, and has a width of about 1,000 feet, chiefly on lots 9 and 10 on these concessions and lot 238 Talbot road.

No detailed log of any of the oil wells here was obtained, but the logs apparently are very similar to those in Gosfield township.

Log of well drilled by Fairbanks and Carman at Leamington:

Sand	10 feet	Surface 100 feet.
Clay	80 "	
Gravel	10 "	

Limestone was struck at about 100 feet which continued together with gypsum and dolomite formations to the finish of the well at 1,091 feet. Fresh water was cased

[24] Journal Can. Min. Inst., Vol. III, page 74.

off at 710 feet. Some gas was met with at 765 and 960 feet and gradually increasing to 1,060 feet. At 1,080 feet sprayed oil, the flow of which increased at 1,082 feet. The gas was very strong at 1,070 feet, blowing cuttings out of the hole, and at 1,080 feet probably made one million feet per day. The well was deepened to 1,091 feet and showed but little water until it had flowed a number of days.

The oil comes from the Guelph formation at a depth of about 1,040 feet in the southern end of the field, and about 1,125 feet in the northern part.

The Leamington Oil Company, which is the oldest concern in the field, completed its twenty-first well on March 20th, 1905. Out of these twenty-one wells, eighteen are productive.

The United Oil and Gas Company have seven producing wells out of eleven put down.

The Detroit and Leamington Company have three producing wells.

The Detroit and Dominion Company have one producing well. This is the Jackson well, which started flowing 400 barrels a day after being shot, in a few days settling down to 100 barrels a day.

The Hickey Oil Company have four producing wells. The Hickey No. 1 was shot 1st December 1904, and flowed for one month. The Hickey No. 4 on the Wales farm, one and one-half miles north of the Jackson gusher, started off at the rate of 1,200 barrels a day, but later settled down to about 200 barrels a day.

The British America Company have one producing well.

The South Essex Oil and Gas Company have a producing well on lot 10, south of the Talbot road.

The Major Syndicate have two wells on lot 10 in the first concession of Mersea township, producing on an average five barrels per day.

The Lake Orion Oil and Gas Company have one producing well, which began to flow at the rate of 150 barrels per day. This is on the farm directly north of the Wales farm, on which the Hickey gusher is located.

The Buffalo and Leamington Company have one producing well on lot 9, concession 9, Mersea. The well has a depth of 1,125 feet. All the wells are shot with about 50 quarts of nitro-glycerine.

In addition to the oil wells there are three or four gas wells, which are in the new oil field north of the old gas field, one of which (No. 3, Rymal) produced at first 1,300,000 cubic feet per day. This well was brought in in February, 1904. These gas wells supply the town of Leamington, and also fuel for drilling and pumping.

At Comber on the Michigan Central Railway, eight wells have been sunk, of which six are producing on an average two barrels per day.

The following is the record of a deep well drilled for the Leamington Oil Co. on Dr. Albert Foster's farm, East Lot 239, North Talbot Road. Commenced March 18th 1905, and completed June 27th:

Feet.	
89	10 feet drive pipe.
585	8 feet casing.
1095	Top salt sand.
1500	Top blue lime.
1556	6¼ feet casing (red rock).
1566	Top slate.
1650	" Clinton lime.
1700	" Red rock.
1850	" slate.
1870	" Red rock.
1950	" lime.
1970	" shale.
2275	" slate.
2488-9	" Trenton rock.
Total depth, 2896 feet	

The well was shot June 24th with 226 quarts of glycerine.

Log of well on lot 7 in the third concession of Tilbury West:

Surface	120 feet	
Limestone	163 "	Corniferous.
Sandstone	20 "	Oriskany.
Limestone and shale	897 "	Onondaga.
Crystalline dolomite	183 "	Guelph.

Oil was struck at 1,200 feet, and nearly 100 feet of oil rock was passed through.

The company operating at Comber is the Sovereign Oil Company.

Mr. Brumell[25] cites a well drilled in 1889 at Blytheswood on lot 7, concession 9, Mersea, to the depth of about 1,200 feet. A small flow of gas was obtained at 1,050 feet, followed at 1,150 feet by a heavy flow of salt water. Oil was not found.

This well is just west of a well sunk on lot 9, concession 9, Mersea, the year in which oil was found, further evidence of the narrowness of the productive area in the Leamington oil field.

Pelee Island

Drilling has been carried on for a number of years on this island in search of gas and oil, with a moderate amount of success. Oil has been found at a depth of about 750 feet.

Borings examined by Dr. Ami, of the Geological Survey Department, give:

Surface drift	58 feet
Corniferous and Oriskany	222 "
For the most part impure fossiliferous limestone with corals, shells and carbonaceous matter.	
Measures unrecorded but probably Oriskany sandstone	44 "
Lower Helderberg and Onondaga	458 "
Consisting of gypsum and gypsiferous dolomites, light yellow, dark gray and bluish gray in color.	
Total depth	782 "

25 G. S. C., 1890-91, page 84, Q.

CEMENT INDUSTRY OF ONTARIO

BY P GILLESPIE

[NOTE.—In the preparation of this article, the following publications were consulted, and the assistance obtained therefrom is gratefully acknowledged: Butler's Portland Cement, Geological Survey of Michigan, Vol. VIII, 1903, Reports of Geological Survey of Canada, Geological Survey of Ohio, 1904, Reports of the American Society for Testing Materials, Vol. II, 1902, and Cumming's American Cements.—P. G.]

"An artificial mixture of lime and clay in proper proportions, calcined to a clinker at a temperature of incipient fusion and finely ground, is called Portland cement" Its manufacture dates from the year 1824, when Joseph Aspdin, a Leeds brickmaker, first put his product on the market. It was designated by him "Portland" cement, from its fancied resemblance when hardened to the well-known colitic limestone quarried on the island of Portland, on the south coast of England, and for centuries used as a building material.

More the result of accident than of purposeful investigation, Aspdin's discovery is like many others of modern times. He mixed the pulverized limestone from the macadamized highways with clay and water. The mixture was dried and burned to a clinker in a kiln. The clinker thus produced was afterwards ground, and its setting and hardening properties on the addition of water rendered it a useful material in construction. In the following year, 1825, he built a factory for its production at Wakefield, and it is said that his cement was employed by Sir I. K. Brunel in 1828 in the construction of the Thames tunnel.

Two years after the registration of Aspdin's patent, Maj.-Gen. Sir C. W. Pasley commenced a series of experiments on artificial cements at Chatham dockyard, which in the light of his time were very gratifying. His raw materials at first were chalk and brick loam, but the supply of the latter having become exhausted, Medway blue clay was substituted, a remarkably good product, everything considered, being the result.

So far as records inform us, these two were the pioneers in an industry which during the last quarter of a century, and especially during the last decade, has grown to gigantic proportions. The chief competitor of the new Portland cement was the so-called Roman cement, which since the time of John Smeaton had been manufactured in England. He it was who first discovered that the cause of hydraulicity in certain limestones is the presence of clay in the stone. That was in 1756. Thenceforward the burning and grinding of nodules of clayey limestone found along the English seacoast, became a profitable business. The product was known as "Roman cement," analogous of course to modern natural cement, and it was from the manufacturers of this that the greatest early opposition to the introduction of Portland cement came.

Many failures mark the first quarter century of the history of Portland cement, chiefly no doubt to lack of scientific direction, and although public competitive tests had as early as 1843 conclusively established the superiority of the new article over the old, conservative England was exceedingly slow to admit the fact. At the England and Colonial Exhibition in 1851, it received its first great and successful advertisement and from that time on its use has steadily extended.

INGREDIENTS OF CEMENT

The two essential ingredients in the manufacture of Portland cement are lime and clay. In America, the former occurs either as limestone or as marl. While in Ontario all the plants save one employ marl as the source of the lime, it is interesting to note that but sixteen per cent. of the total output of the United States is made from that material.

Marl

The existence of deposits of marl at the bottom of many of our smaller lakes has been explained in various ways. Some there are who contend that marl is composed of the shells of fresh water mollusks. As most marls contain shells more or less perfectly preserved, color is lent to this hypothesis. It is further argued that through erosive and grinding agencies, shells have lost their characteristic forms, and that that portion of all marl which is microscopic and formless has had its origin through the crushing and grinding of shells. Other investigators advance the view that marl has had its beginning through the deposition of calcium carbonate from water containing this salt in solution.

It is a well-known fact in elementary chemistry that water containing carbon dioxide in solution will dissolve a much greater quantity of calcium carbonate than will water in which this gas is not present. It is also well known that when for any reason the gas is expelled from the water, the calcium and magnesium carbonates are deposited as a finely divided powder. It is therefore contended that when water, containing carbon dioxide under pressure and holding in solution a greater quantity of carbonate than it could retain, were it not for the presence of the gas, is discharged from some underground channel, the gas owing to reduced pressure, escapes to the air. The salts are then deposited by precipitation on the sides and bottom of the stream or lake as carbonates of calcium and magnesium, and form the familiar marls of our lakes.

NOT ALWAYS AN ORGANIC PRODUCT

The fact that isolated shells are found perfectly intact at depths of twenty feet in places, would point to the conclusion that shells are not the sole source of marl. For, if that were the case, the number of wholly or partially preserved shells would be much larger at these depths than it actually is. Careful determinations of the quantity of shells and shell fragments present in several samples of marl are reported by Professor C. A. Davis, of the Geological Survey of the State of Michigan, and are included in the publications of the Board of Geological Survey for 1903. Selecting four samples at random, he found that shells and shell fragments comprise on an average little more than a half of one per cent., and in one instance only does it exceed one per cent. The conclusion arrived at in the discussion is that shells are but a minor element in the composition of marl, and that their existence and growth depend on much the same causes as those which produce the marl itself. These causes, recent investigation leads us to believe, are found in the fact that our underground springs contain solution the carbonates of calcium and magnesium, washed from the soil from which the springs are drawn. Differences in opinion now are not so much as to the source of the deposit, as to the cause of its precipitation. That the underground feeders of our lakes are the source of supply would seem to be the theory set forth in The Geology of Canada, 1863, which we quote:

"Although belonging to the present geological period, this marl is not always of recent formation; inasmuch as the beds of it are sometimes overlaid by peat, or by soil supporting a growth of large trees. At other times, however, the marl covers the bottom of shallow lakes or ponds, and is evidently in the process of deposition. It appears to be formed by the waters of springs, highly charged with lime, which is at first held in solution as bicarbonate, but is deposited when these waters come to the air. It is thus similar in its origin to the deposits of calcareous tufa, which occur in many places where such calcareous springs flow over earth, rocks and vegetation instead of falling into lakes or marshes. The presence of carbonate of lime is a necessary condition of the development of shells, and various species of mollusca abound in such waters. These by their remains, which often form a considerable portion of the deposits, give to them the name of 'shell marl,' which is frequently applied. This substance is white and earthly in its aspect and, unless mingled with clay, is a nearly pure carbonate of lime."

Whether the writer of the above held that the water is a surcharged solution of carbonate due to the presence of CO_2, is not altogether clear. Our acceptance of the

theory will depend on whether it can be shown that the percentage of calcium and magnesium carbonates present in our ground waters is above the quantity which can be dissolved in water free from carbonic acid gas. Referring again to Prof. Davis' report above quoted we read:

"According to Treadwell and Reuter's carefully made experiments, water at ordinary temperature and pressure containing no free CO_2, may yet contain permanently 0.38509 grams of calcium bicarbonate, or .238 grams $CaCO_3$ per litre. . . Now the analyses of waters from Michigan show a content of calcium carbonate from .175 to .250 grams per litre. . . . . With this in mind it can easily be seen that the carbonated waters of our springs and marl lakes are generally far below the point of precipitation."

How then is the mineral content of our springs deposited? Clearly, the cause must be looked for elsewhere.

It is a familiar phenomenon in the study of plant life that all chlorophyll-bearing plants, terrestrial or aquatic, absorb carbonic acid gas through the stomata or breathing pores of their leaves. The leaf is the laboratory of the plant; in this laboratory, the gaseous food is assimilated. The carbon and a part of the oxygen composing the carbonic acid gas are retained to build up its own tissues, and the rest of the oxygen rejected to the air. A second chemical reaction is instructive. It illustrates the effect of this free oxygen on the bicarbonates of which calcium bicarbonate, $Ca\,H_2\,(CO_3)_2$ is typical. The following is the equation:

$$Ca\,H_2\,(CO_3)_2 + O = CaCO_3 + CO_2 + O + H_2O$$

In words, it is this: The bicarbonate of calcium in the presence of oxygen becomes the normal carbonate with evolution of carbon dioxide, oxygen and water. The oxygen being nascent, is doubtless free to repeat the process. This then is given as an explanation of the incrustations of carbonate on water plants, which are observable in marl bogs and with which many of us are familiar. The conditions are but two in number; a carbonate-charged water, and the presence of vegetable life. The Michigan Survey report is quoted in conclusion:

"One of the strongest of reasons why the purely chemical theory is not true is lack of marl in some shallows and its presence in others. The lime-bearing water must be distributed evenly to all shallows and should precipitate upon all at an equal depth. This is often contrary to fact, while on the other hand it would be impossible for a local precipitation to be brought about in the presence and only in the presence of water plants producing oxygen."

COMPOSITION OF MARL

An analysis of marl usually reveals the presence of the following ingredients: carbonate of calcium, carbonate of magnesium, ferric oxide, oxide of aluminum, silica, organic matter and anhydrous sulphuric acid.

The calcium carbonate is the essential ingredient in marl, and should of course be a very high percentage of the whole at least ninety per cent. The purest marls run from ninety-five to ninety-seven per cent. of calcium carbonate.

Magnesium carbonate is analogous in its chemical composition and properties to calcium carbonate, but it is characteristic of marl that when the latter is high in the analysis, the magnesium carbonate is low. Further, it has not been shown that this ingredient improves the cement in any way, and if present in large quantities is a positive detriment. The magnesium carbonate should probably not exceed three per cent.

Iron and aluminum, belonging to the same chemical group, are frequently reported together in an analysis. The iron acts as a necessary flux. It will generally be noticed that both ferric oxide and alumina are likely to be light where organic matter is high. Two and a half per cent. is considered the limit for the combined oxides.

The amount of silica in a good marl is small. It ought not to exceed three or four per cent. in the sample. Its presence in a marl interferes with the adjustment of the slurry, and although it is a constituent of clay, it does not make so intimate a mixture with the lime of the marl as does the clay silica.

Sulphur compounds are a positive injury above a two or three per cent. limit, If present in quantities much exceeding this, certain somewhat complex chemical reactions result, which, after the cement has been used, may lead to ultimate disintegration.

Organic matter is more negative in its character and effects than positive. While it increases the bulk of the marl, it really neither adds to nor subtracts from its fitness as an ingredient in cement manufacture, since the organic matter is practically all burned in the process. A greater quantity of course is required to produce the same amount of cement, and hence the cost of manufacture is correspondingly increased. An examination of analyses shows that marls free from organic matter are likely also to be free from injurious ingredients. Elsewhere are given the results of analyses of samples of the marls from which our Ontario Portland cements are made.

MARL DEPOSITS IN ONTARIO

In the descriptions of plants, to follow, reference will be made to Ontario marl deposits which have been or are soon to be worked. There are many other areas where, for various reasons, nothing in the way of development has been undertaken. Among these reasons may be mentioned smallness of deposit, remoteness from railways or other shipping facilities, and the possible over-production which of late years has been feared by the more conservative observer in Ontario. In any case, it would appear as if there is little danger of a dearth of this material in the Province for many years to come. In 1902, the Geological Survey of Canada published a little brochure giving a list of the more important Canadian marl deposits. The compiling was done by Dr. R. W. Ells, and no doubt was tolerably correct as to the areas known up to that time. The following list is selected mainly from the pamphlet referred to. and gives a fairly good idea of the number and some detail as to the extent of these deposits. Those which have been worked will be dealt with similarly later on. Many deposits of marl are also enumerated in the Reports of the Bureau of Mines—particularly Part II of the Thirteenth Report, "The Limestones of Ontario."

In the township of Storrington, Frontenac county, about ten miles north of Kingston, there is a large deposit of marl occupying the bottom of Loughborough lake. more especially the southeastern portion. The depth of water is not great, and although the deposit is believed to be very large, little concerning its depth seems to be known. Marl is also found in the bottoms of many of the lakes between this place and White lake in Olden township. These deposits are convenient to both the Rideau canal and the Kingston and Pembroke Railway.

Deposits are said to occur near the city of Belleville, Hastings county, but no data regarding their size are given.

In the township of Yonge, Leeds county, near the village of Athens, there are several beds of marl which have never been exploited. One of these is on lot 13, range VIII, and is said to occur over an area of at least twenty-five acres, with an ascertained depth of seven to fifteen feet. The material is also reported as occurring on lots 7, 8 and 9, range IX, at the bottom of Mud lake, and possibly at other points in the vicinity. In the township of Elmsley in the same county, it is found underlying portions of Bass lake, of a thickness from three to four feet, but the exact extent of the deposit is not known.

Nature has been very generous to Renfrew county in the matter of marl deposits. In the township of Wilberforce, near the Bonnechére river, and about three miles from the line of the Canadian Pacific railway, between Douglas and Eganville, is Mink lake. This lake has an area of one thousand acres, and marl is believed to cover most of the bed of the lake, being visible in many places. The depth is known to be nine feet in places, and no doubt much exceeds this in others. The lake could be easily drained. In the towship of McNab, the lower end of White lake shows a large area of marl, extending over some seven hundred acres. The depth is from five to seven

feet, and the difficulties in the way of draining are inconsiderable. The distance from Arnprior and railway communication will be about eight miles. In the township of Ross several deposits are known to occur in a chain of lakes which extend southeast from Muskrat lake, near Cobden village, and which are believed to form the prehistoric valley of the Ottawa river, extending from Pembroke eastward. At Green lake, on lot 13, range IV, the marl is found in one place with an exposed area of five acres and a depth of from five to twelve feet. On lot 15, range II, in another small lake, considerable deposits are found, especially near the outlet, and it is supposed the same material underlies the water. Other lakes of the chain also have deposits, the extent of which has not been accurately determined. In the township of Westmeath, on lots nine and ten east from B, shell marl on the shores of a small lake is known to occur, but to what extent is uncertain.

In Emerald lake, Nipissing district, near lake Temiskaming, there is a deposit of marl which is thought to be of considerable extent. With the opening of the adjacent territory, this material may have an early commercial value.

"Among other places where the material is found in this Province, but where the extent of the deposits has not been determined, may be mentioned lot 13, range IV. township of Lavant, Lanark county, six acres in area, and seven feet deep; Chalk Lake, lots 1 and 2, range I., and lot 1, range II., township of Reach, Ontario county, a lake of seventy-five acres with a marl bottom, the thickness of which is considerable, but is not definitely stated. In this list may be included White lake, lots 18 and 19. range IX, Huntingdon, Hastings county, the deposit extending out under the waters of the lake and found to be thirty feet thick in places; and the Eramosa branch of Green river, Eramosa township, Wellington county, where the deposit is at least three feet in thickness, with a covering of three feet of peat."

In Artemesia township, Grey county, there is a seven-foot depth, covering an area of at least twelve acres. At the lower northwest end of Clear lake, in the township of Sebastopol, Renfrew county, there is a large quantity of marl. This deposit and several others in adjacent lakes will probably some time prove an attraction for Canadian capital. On the shore of Hemlock or Mackay lake, at New Edinburgh, Ottawa, marl has long been known to exist, extending over one hundred acres or more, with a depth of at least five feet. The deposit is, however, largely covered with soil and forest growth, but has been locally used to some extent in the manufacture of white brick. In Prescott county, in the vicinity of the Ottawa river, on lot 18, range IV, West Hawkesbury, there is an area, the extent of which has not been definitely determined, but it is known to cover from five to ten acres, and to be three feet in depth at least. The marl is covered with four or five feet of peat.

THE VALUE OF A MARL BED

Anything pretending to a discussion of marl deposits would certainly lack completeness without some reference to their latent possibilities. To say that an area of one hundred acres has a deposit of marl running to an average depth of fifteen feet is to give to the ordinary person almost no conception of the potentialities of such a deposit. There are all sorts of conditions which affect the value of a marl proposition, among which will be the water percentage, and the calcium carbonate content, as revealed by a chemical analysis. In order to make an estimate, these two and certain other unknown elements entering into our problem must be assumed.

A barrel of cement contains three hundred and fifty pounds, sixty-three per cent. of which, let us say, is lime. Sixty-three per cent. of three hundred and fifty is two hundred and twenty and a half pounds, which quantity of lime is supplied almost altogether by the marl. Let us assume that the marl in question has a carbonate content of eighty per cent. and contains on dredging say sixty per cent. of water. From this, it follows that one hundred pounds of fresh marl will give forty pounds of dry material, which in turn will give eighty per cent. of forty, or thirty-two pounds of pure calcium carbonate. Now, of calcium carbonate, but fifty-six per cent. is lime. This means that of our hundred pounds of dredged material, only eighteen lb. become

a constitutent of the finished product. Since a barrel of cement requires two hundred and twenty and a half pounds of lime, it is clear that for its manufacture nearly thirteen hundred pounds of wet marl will be required. Again, a cubic yard of our dredged marl will weigh about two thousand five hundred pounds, and so we find that one barrel of cement will be produced from fifty-two hundredths of a cubic yard of wet marl. A plant of three hundred barrels per day capacity would consume one hundred and fifty-six cubic yards per day, or forty-six thousand eight hundred cubic yards per year of three hundred working days.

But, returning to our deposit, we find that one hundred acres of a depth of fifteen feet will contain two million, four hundred and twenty thousand cubic yards of marl, or a sufficient supply at the assumed rate of consumption to last for fifty years.

Manufacturers state that from three-tenths to five-tenths of a cubic yard of marl are necessary to produce a barrel of cement. It will be noticed that the greater of these limits is slightly below that of our computations, the data for which were of course purely hypothetical.

Clays

The silica and alumina required in the manufacture of Portland cement are supplied by the clay or shale, as the case may be. Pure clay may be designated by the formula $Al_2O_3.2SiO_2+2H_2O$, and is therefore a silicate of aluminium. It should be remembered, however, that the silica present exists in the combined or soluble form, and not as granules of sand. Any clay, therefore, that is gritty to the touch or in the teeth, if chewed, is objectionable, for the reason that it probably contains uncombined silica. This in the kiln is very refractory, requiring for its combination with the lime a much more intense heat than does the combined silica of the formula. Cement could, of course, be manufactured by using sand as the source of the silica, were it thought prudent to reduce it by grinding to a state of sufficient fineness, and to employ the greater heat which would be rendered necessary.

The best clays for the manufacture of Portland cement have a greasy, unctuous feel, and are quite smooth to the touch. "Clays which stain the fingers should be avoided as being either too much impregnated with iron compounds or containing a large proportion of organic or other impurities." Clays also containing much calcium carbonate should be avoided, as the percentage of this ingredient is liable to great fluctuation, and its presence in the clay complicates the proportioning of the ingredients very much. A simple test for clay is the application of hot dilute acid. If there is much effervescence on the addition of the acid, the material is objectionable because of the presence of carbonates.

Analyses of an available clay should in all cases be made in order to determine the composition and its uniformity. The same ingredients as in marl may be looked for, but of course in widely different proportions. Preferably the ferric oxide and the alumina should in the analysis be separated. In general, a clay that contains not less than two parts of silica to one of combined iron and alumina is preferred. This in a good sample will be between forty and sixty per cent. Calcium carbonate as stated above, is objectionable, not because of its composition, but because of the difficulty in correctly proportioning the mixture. Oxide of magnesia should not exceed three per cent. Manufacturers tell us that magnesia refuses to unite with the clay at the temperature with which the latter and the lime combine. In consequence, the magnesia remains in the finished cement as the oxide. Like free lime, this expands and disintegrates on the addition of water and in a mortar is likely to cause trouble. Ten per cent. of lime, and two per cent of sulphuric acid, will be the maxima for a good clay.

The following analysis is of a clay that would answer very well as an ingredient of cement:

	Per cent.
SiO_2	61.06
Al_2O_3	18.10
Fe_2O_3	6.65
CaO	1.25
MgO	.53
SO_3	1.05
Loss on ignition (CO_2 and water)	9.20

It will be noticed that the silica is considerably in excess of twice the cambined oxides of iron and alumina, that the lime is nearly down to the one per cent. limit, and that both magnesia and anhydrous sulphuric acid are low. The organic matter and water, being expelled in the process of calcination, do not enter into the reactions in any way, and of course are equivalent to so much inert and useless matter, affecting chiefly the cost of transportation of the raw material. It has been stated elsewhere that a high percentage of alumina will quicken the setting of the finished cement. In the above analysis the alumina is slightly high, ten or twelve per cent. giving the best satisfaction, as a general rule. This defect, however, can be corrected by the addition of gypsum in the usual way.

In general, the process of manufacture consists first in mixing intimately the two ingredients in a finely divided condition; secondly, in subjecting the mixture thus obtained to a heat sufficiently intense to expel the carbon dioxide, and to form a clinker but not to vitrify; and thirdly, in grinding the clinker when cooled to an impalpable powder. The details of the process vary with every plant, but the results sought are identical in all.

Chemical Composition of Cement

An elaborate series of experiments, synthetic and analytic, conducted by Dr. Newberry and others has led to the conclusion that Portland cement is a mixture of silicates and aluminates of lime, chief of which are the tri-calcium silicate ($3CaO.SiO_2$) and the di-calcium aluminate ($2CaO.Al_2O_3$). Moreover, Newberry showed that if lime (CaO) and silica ($SioO_2$) in the proportions indicated by the weights of combination in the first formula, be thoroughly mixed and subjected to sufficient heat, a product showing the hardening properties of Portland cement will result. And further, if lime and alumina (Al_2O_3) be similarly treated, the product will show the phenomenon of setting peculiar to Portland cement. His inference is that these two compounds may and do exist in various proportions in Portland cement, and that there is no fixed or necessary ratio between them. In a cement analysis, iron oxide and alumina are usually reported together, and indeed ferric oxide is supposed to be analogous in its hydraulic effect to alumina. Hence it follows that an analysis high in alumina and iron oxide usually denotes quick setting properties, while a cement high in silica is likely to develop great ultimate hardness. We say "likely," since rapid setting may be due to insufficient mixing or to underburning, while slow setting in cement may be due to overburning.

By a simple calculation involving the atomic weights of the elements concerned, it can be shown that the lime and the silica are in the ratio of 2.8 to 1 by weight in the silicate; and that the lime and alumina are in the ratio of 1.1 to 1 in the aluminate. From this Newberry deduced his "hydraulic index" or ratio between the basic element on the one hand, ad the acid elements on the other. It is usually stated as follows: multiply the percentage of silica by 2.8 and the percentage of alumina by 1.1. The sum will be the maximum percentage of lime to be looked for in the cement.

The following analysis of a cement is taken at random from the directory of American Cement Industries for 1904, p. 38.

Lime	62.30
Magnesia	1.20
Silica	21.30
Alumina	6.95
Oxide of Iron	2.00
Sulphuric Acid	0.98
Loss on Ignition, Alkalies	4.52

Now $21.30 + 2.8 + 6.95 \times 1.1 = 67.28$. This is seen at once to exceed the percentage of lime (62.30) as given in the report. Without considering the similarity between magnesia and lime, we find that the acid elements present are capable of combining with 67.28 units of weight of lime. That there are only 62.30 units of lime present according to the analysis is due partly to the fact that the formula represents the maximum quantity of lime that will combine with the silica and alumina, and partly to the fact that the manufacturer choses to attempt less than this maximum rather than run the risk of overliming his cement. There are other sources of error. The ash remaining from the process of burning passes into the cement. This is largely silica and alumina, and of course operates to give the impression that the cement is overclayed. Then too, gypsum is always added to lengthen the time of setting, and if this be reported as lime and sulphur trioxide, it will increase somewhat the percentage of lime.

The pernicious ingredient in cement is free lime. If clay be in excess its effect is not positive, since clay in cement is inert matter. Free lime on the other hand will produce dire results. In time through the action of atmospheric moisture or of water if submerged, the lime slacks and the mortar or concrete of which it is a constituent disintegrates and falls to pieces. Experience, however, shows that an excess of free lime reaching one and a half per cent. is not likely to manifest any destructive tendencies. Still, manufacturers preferring to take no risks of overliming, usually allow their product to contain a small excesss of clay or sand.

Now it must be borne in mind that a chemical analysis of cement may not reveal its true character as a material for construction. Ordinary analyses do not distinguish between free and combined lime. A cement may be properly mixed, but improperly burned, in which case a chemical analysis would fail to detect the defect. The past test to be described later, would be a much more reliable indication of the value of the cement.

COST OF CEMENT PLANT

The cost of a modern plant manufacturing Portland cement from marl and clay may be put at fifty thousand dollars per rotary kiln installed. This estimate includes the cost of dredging and transporting the raw materials, that of wash mills, grinders, storage tanks, rotary kilns, coolers, finished grinder and stock packing houses. The equipment for power generation is included, and also the entire cost of erecting suitable buildings, everything to be modern and first class. Assuming that the output of each rotary is one hundred barrels per day, we have the investment in plant as five hundred dollars for each barrel of the rated daily capacity. Doubtless by the installation of some form of continuous upright masonry kiln, the cost might be considerably reduced, yet the wage account where such methods are employed is always much higher per unit of output, the amount of manual labor necessitated being considerably greater.

Experience in Ontario and the United States has proved, and without a doubt will continue to demonstrate that the higher profits in the cement industry are realized by those plants having a large capacity. It is the smaller manufacturers in Ontario to-day who find it most difficult to pay dividends in the present condition of the cement market.

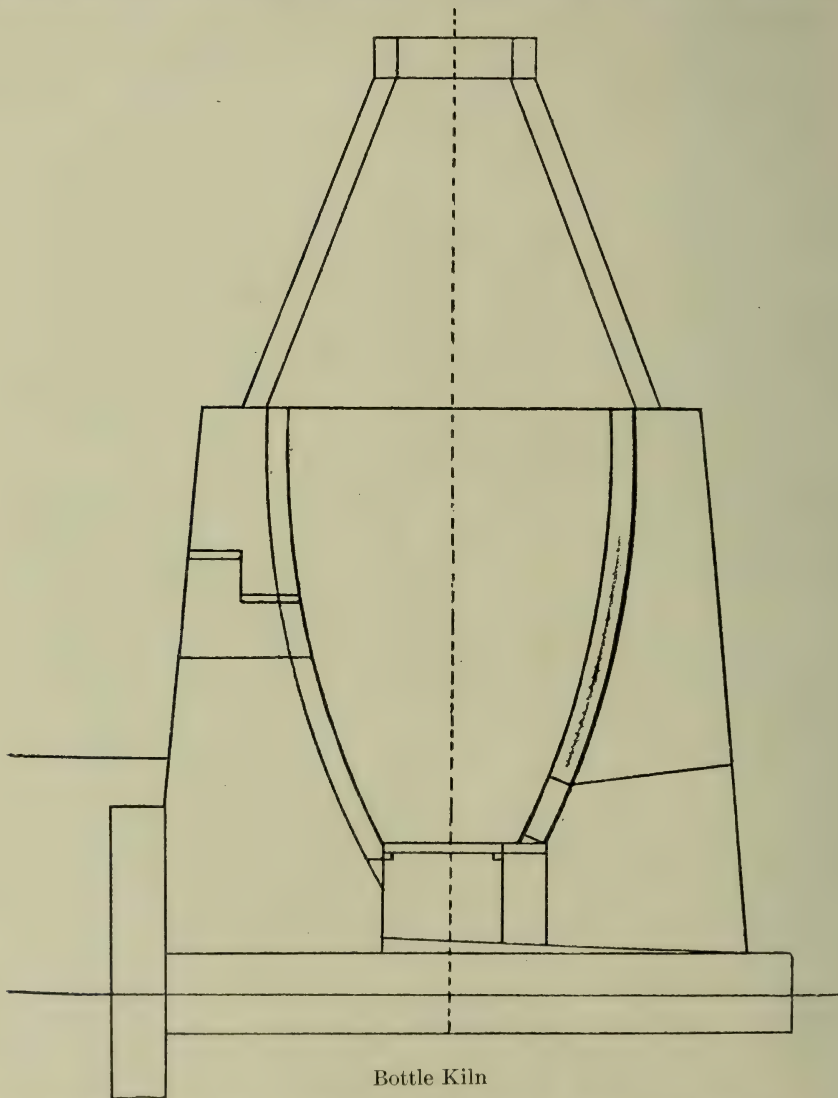
APPLIANCES USED IN MAKING CEMENT

Wash Mills

Washmills are usually built with concrete sides and bottom, and are circular, hexagonal or octagonal in form. The diameter is from eighteen to twenty feet, and the depth is about eight feet. There is an upright centre shaft having horizontal arms or spokes, which carry "drags," usually three in number. Washmills are employed for the preliminary mixing.

Intermittent Kilns

Of intermittent kilns, there are two types, the "bottle" kiln and the Batchelor. The former as the name would indicate, is in vertical section, shaped somewhat like a bottle. The outer structure is built of brick or stone, and the lining, on account of the excessive heat to which it is exposed, is of fine clay. The fire is started on the



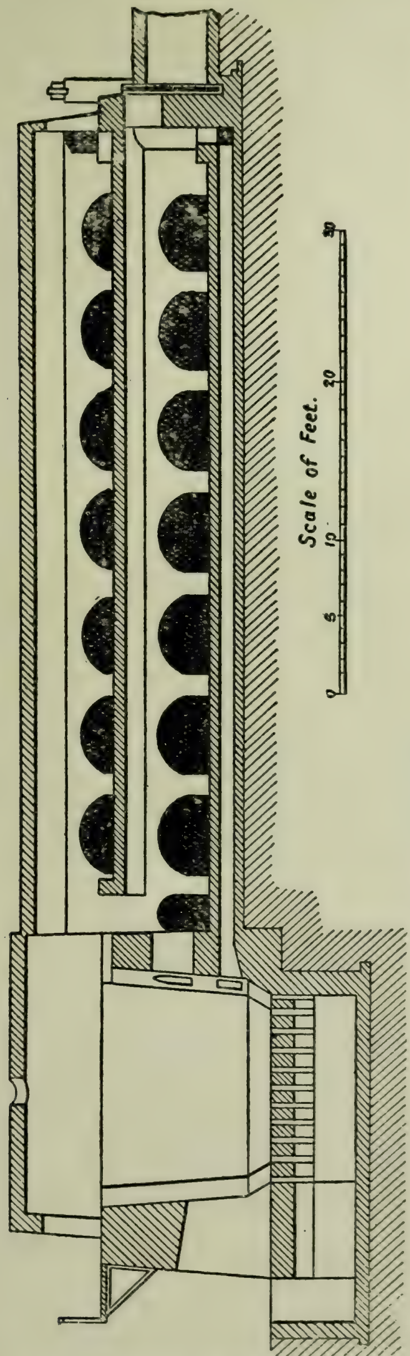
Bottle Kiln

grating below and when well under way, alternate layers of coke and dried slurry are laid in. When the burning is completed, and the clinker allowed to cool, it is "drawn." The processes of loading, firing and sorting the clinker all require considerable skill, and of a kind, too, wholly born of experience.

The Batchelor Kiln

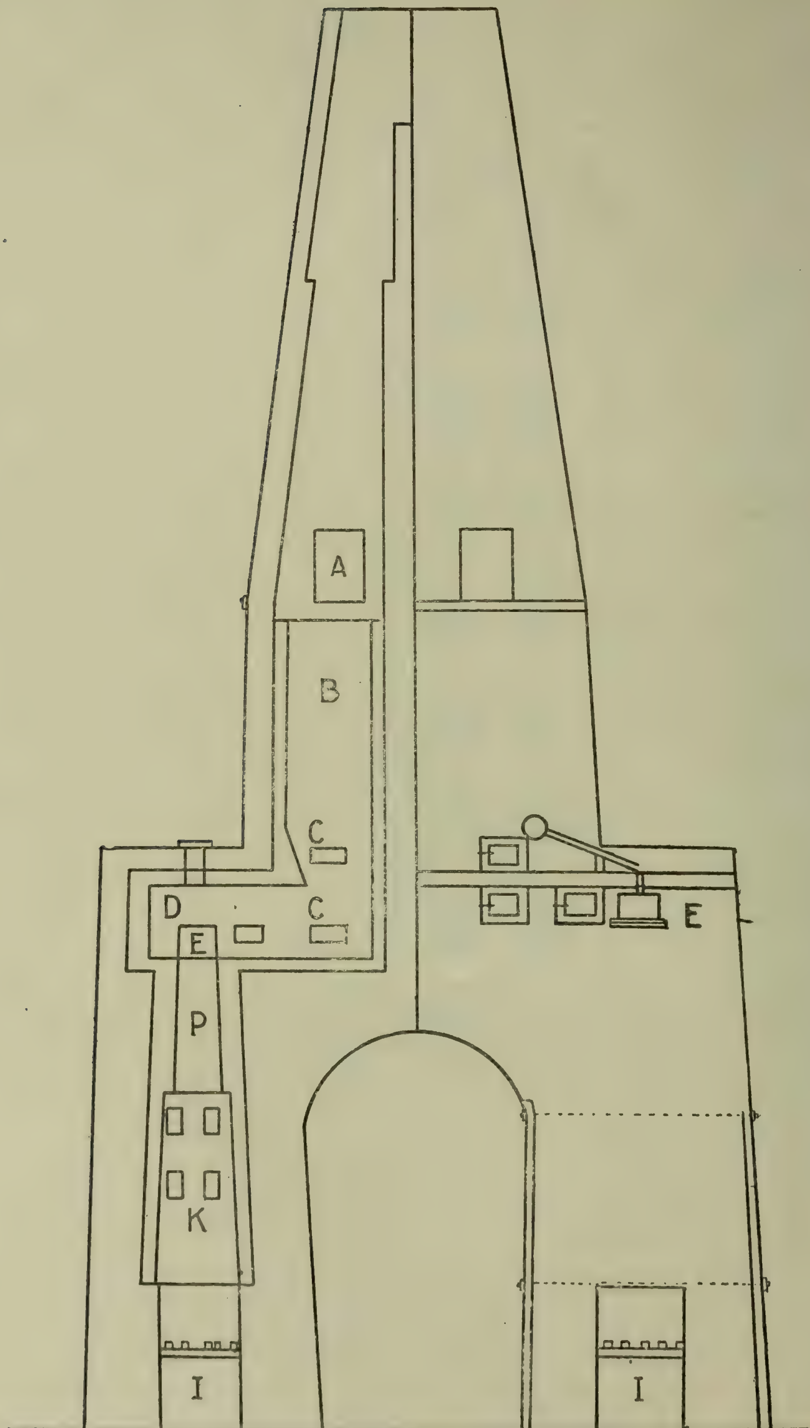
No attempt to utilize the waste heat from the firing chamber is made in the bottle kiln. This in done in the Batchelor kiln. If we conceive a long covered archway with a cement floor, annexed to the bottle kiln in such a way that the escaping

gases are obliged to pass through it on their way to the stack, we have the principle of the Batchelor kiln. The slurry is pumped over this floor to a depth of a few inches.



Batchelor Kiln. The kiln proper is the chamber on the left. The two slurry drying floors are shown to the right, one along the other. (Butler's "Portland Cement.")

and while one charge is being clinkered in the furnace of the kiln, a second is being dried on the archway floor. The Batchelor kilns are usually constructed in batteries of six, having a single stack to which all flues lead.



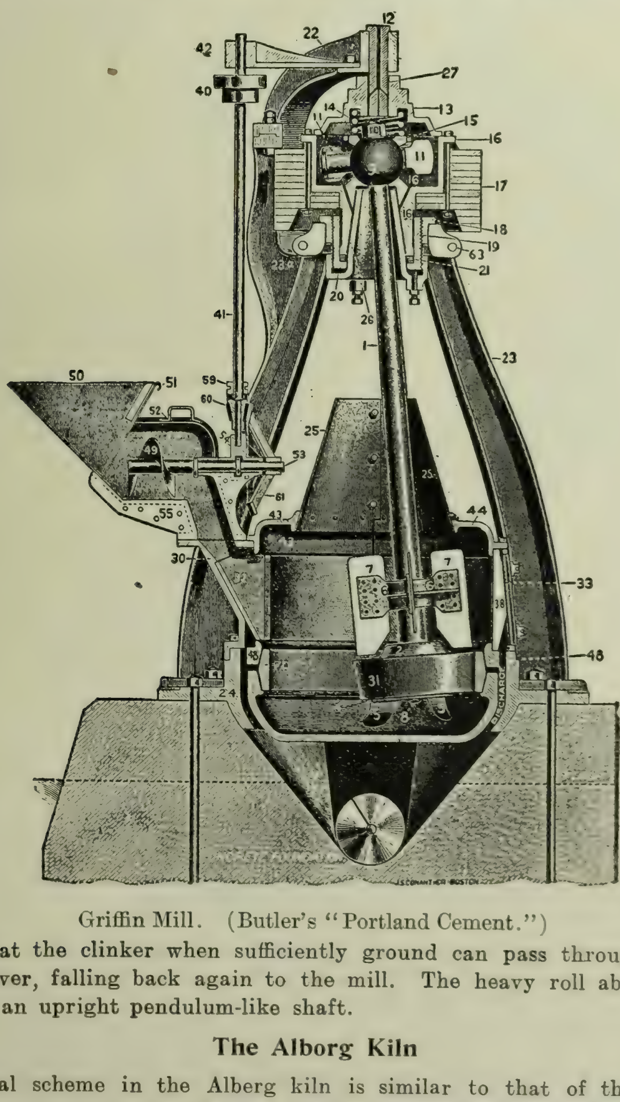
Dietsch Kiln. Half elevation, half section. A.--Loading port. B.—Heating chamber. E.—Full charging port. P.—Burning chamber. K.—Cooling chamber,

The Dietsch Kiln

The Dietsch kiln is one of the continuous types. The "forewarmer" is really the lower part of the stack, there being here a shelf or ledge which prevents the mass of slurry bricks above from falling down. The coal is charged into the furnace from the floor beneath that from which the dried slurry is charged. The "drawing" is done from below, every four or six hours, and to replace the material thus drawn, a fresh supply is dragged by hand from the ledge above referred to. The kiln is provided with suitable "ports" or "eyes" for firing and loosening the bricks when "hung up."

The Griffin Mill

This mill is used at some factories for grinding the finished product. It consists of a steel ring against the inside surface of which a heavy steel roll is made to revolve. This roll, by centrifugal force, exerts a pressure against the steel ring. Screens are



Griffin Mill. (Butler's "Portland Cement.")

provided so that the clinker when sufficiently ground can pass through, the coarser particles, however, falling back again to the mill. The heavy roll above referred to is attached to an upright pendulum-like shaft.

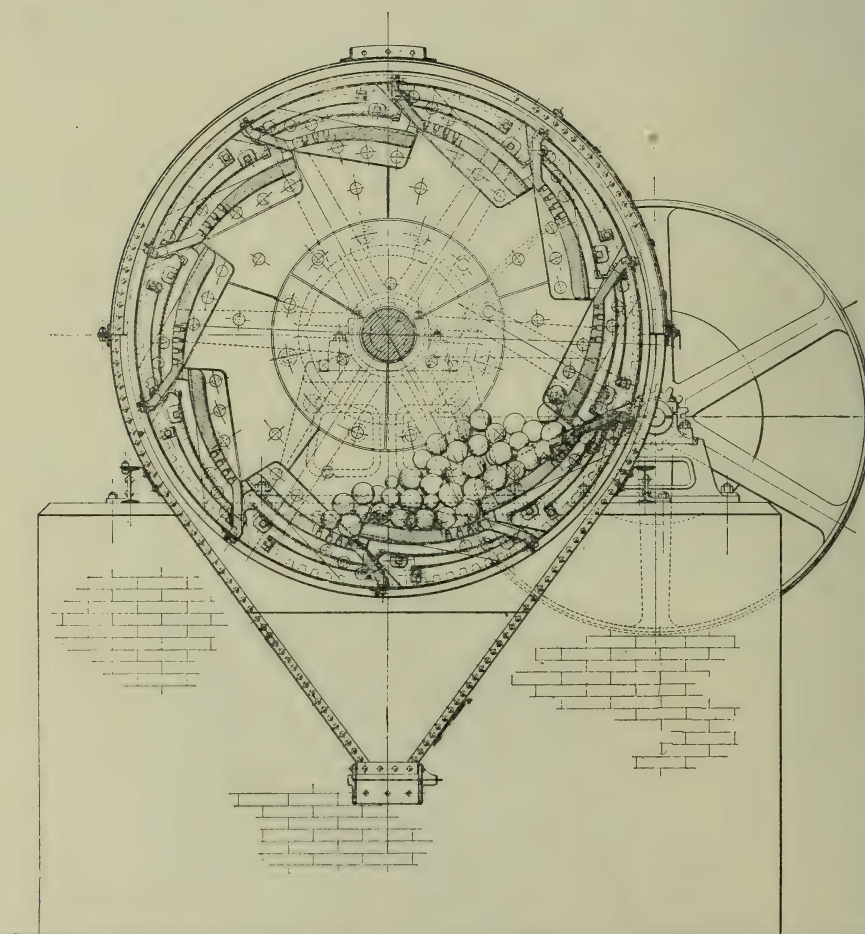
The Alborg Kiln

The general scheme in the Alberg kiln is similar to that of the Dietsch kiln. There is, however, no ledge in the Alborg kiln. The narrowest portion of the kiln, or

"throat" occurs where the coal is charged into the kiln. Above this, the slurry bricks part with their moisture, and below it, the firing takes place. Below the firing zone the cooling occurs. No attempt is made to utilize the waste heat.

The Rotary Kiln

The rotary kiln is simply a huge revolving cylinder of boiler steel set slightly on an incline. The lower end is closed by a "hood" mounted on wheels, so that it can be rolled back at pleasure. Through this hood passes the pipe which admits the fuel, usually ground coal. The fluid slurry is pumped in at the upper end. Rotary kilns have a capacity of about one hundred barrels per day, depending on the kind of slurry and the length of the kiln.

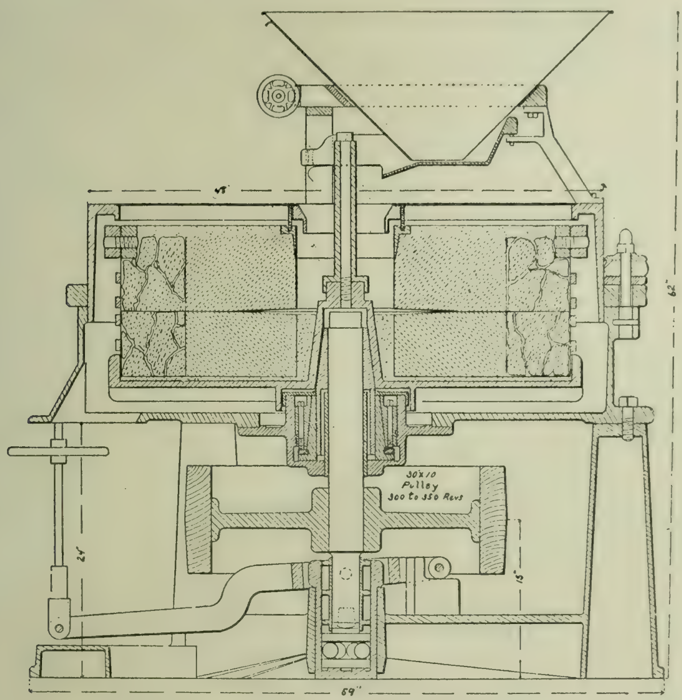


Gates Ball Mill. Cross-section showing shields and screens. (Allis-Chalmers Co.)

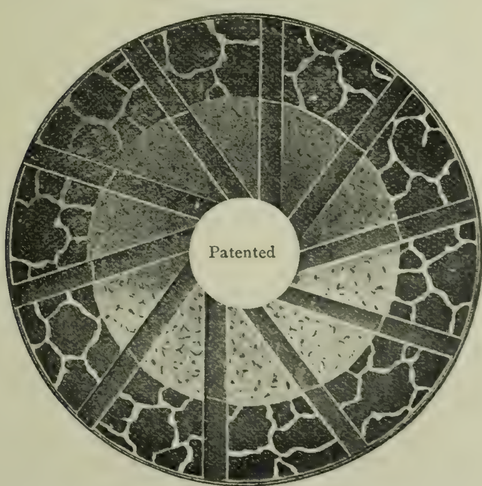
Ball Mills

Ball mills are employed to do the coarser grinding of the clinker only. They are in the form of short cylinders revolving on their axes and containing a number of large steel balls. The circumference of the mill is provided with overlapping "wearing plates" and two sizes of screens. The material as it is reduced to sufficient fineness passes through holes in the plates and through the meshes in the sieves, all particles

not sufficiently reduced to pass the finer of the sieves being returned to the mill in the process of revolving. The finer particles pass to a hopper below. The clinker is fed in through one of the trunnions of the mill.



Emery Mill; cross section. (The Sturtevant Co.)



Rock Emery Millstone. (The Sturtevant Co.)

Sturtevant Emery Stones

These mills are used both for wet and dry grinding. They consist of two built-up stones. The parts are of natural emery rock, and are mounted as are the well-known buhr stones at one time very common in flour mills. Emery grinding stones are mounted vertically as well as horizontally.

Tube Mills

Tube mills are cylindrical in form, usually about five by twenty feet. They are employed in both raw and final grinding. A tube mill must of course be lined with some resisting material, usually silex stone, since it is partially filled with flint pebbles, which accomplish the grinding of the clinker or slurry, as the case may be. As in the ball mills, the feed is through one of the trunnions of the mill.

The Gates Crushers

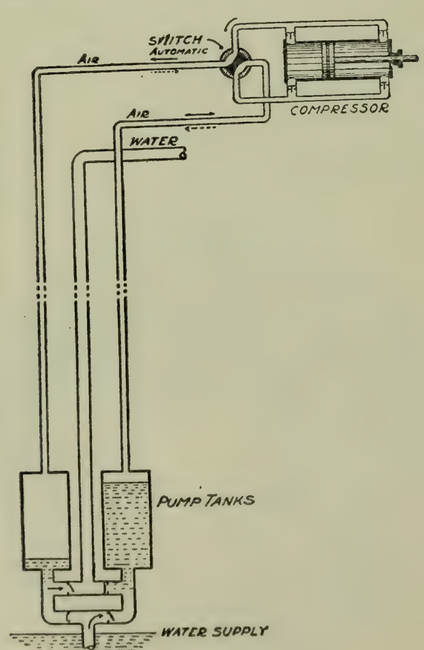
The Gates rock and ore breaker is of the gyratory type, and is capable of crushing from 75 to 125 tons per hour, depending on the size of the machine employed. The size to which the rock can be reduced can be controlled at will within certain limits. The axis of the mill is vertical.

The Mosser Tower Cooler

The Mosser cooler consists of a circular tank eight feet in diameter, and thirty-two feet high, fitted with internal blast pipes and cones. The hot clinker is elevated outside and dumped in at the top. The tank is supposed to be kept practically full of clinker, which is withdrawn from the bottom as fast as it is supplied at the top A Mosser cooler will handle the output of four rotary kilns.

The Harris Pneumatic System

This system is employed for pumping all kinds of fluids including wet marl and slurry. The accompanying figure is diagrammatic, but serves to illustrate the method. The operation is as follows:



The Harris System of Marl Pumping. (Pneumatic Engineering Co.)

"Suppose the compressor to be in operation and the switch set as in the figure. The air will be drawn out of the right tank and forced into the left one, and in so doing will draw the fluid into the former and force it out of the latter. The charge of air in the system is so adjusted that when one tank is emptied the other is filled, and at that moment the switch will be automatically thrown reversing the pipe connections and thereby reversing the action in the tanks."

CEMENT PLANTS OF ONTARIO

Following is a description of the various cement-making plants in Ontario, including those in process of construction, as well as those actually in operation, as seen by the writer at the close of 1904 and the beginning of 1905.

The Belleville Portland Cement Company

President......	A. Ansley.
Vice-Presidents........	John McGowan, M. P. Miller Lash.
Manager and Sec.-Treas.	J. W. McNab, Belleville.
Works	Point Ann, Ont.
Authorized capital	$2,500,000.

That this company will begin the manufacture of cement with a singularly valuable asset in the shape of natural opportunities is at once manifest. These natural opportunities are, first, almost inexhaustible deposits of raw materials conveniently situated; secondly, a good harbour, and thirdly, first-class shipping facilities by water.

The Belleville Portland Cement Company, unlike any of its competitors in Ontario, proposes to use limestone and clay as its raw materials, and for this purpose is rapidly carrying to completion extensive works at the Point Ann peninsula, on the Bay of Quinte, some four miles east of the city of Belleville. The works are connected with the Grand Trunk Company's line at Belleville station by a standard gauge track, for the construction and operation of which a railway charter was obtained. The limestone is exposed in most places and comprises an area of 386 acres. The depth, ascertained by borings, is known to be upwards of thirty feet. The clay is found on the same property, part of it indeed but a few hundred feet from the plant. Other deposits are on the line of the company's railway, so that delivery without freight charges will be assured. The total clay area is in the neighborhood of 40 acres, and runs to a depth of sixteen feet in places.

The limestone will be brought to the works by narrow gauge tracks, and will receive its preliminary treatment in two Gates gyratory stone crushers, each having a capacity of forty tons per hour. Five Sturtevant crushers of the coffee-mill style will next take charge of the stone, reducing it approximately to a quarter-inch mesh.

The clay also will be brought from the beds by narrow gauge cars, and will be first passed through a rotary drier. This consists essentially of a cylinder of boiler plate sixty feet long, five feet in diameter, and partitioned longitudinally by plates which divide its cross-section into quadrants. It is made to revolve on its axis, which is placed in a position nearly horizontal. A furnace is built at the lower end in such a way that the waste gases therefrom must pass through the cylinder on their way to the stack with which the upper end is connected. The clay is fed into this upper end through the rotary motion of the cylinder, and is finally discharged from the lower end, having come in contact with the hot furnace gases in its progress through. Ordinary soft coal will be the fuel employed at the Belleville plant. The crushed rock and clay will then be mixed in proper proportions by specially constructed weighing machines, after which they will be together passed through a second drier identical with the first. The object of this is to still further reduce the moisture present in the clay, and to remove any surface or other water adhering to the stone.

Screw conveyors will carry the material to a storage bin in the mill room of five hundred tons capacity. As desired, it will be admitted to Griffin mills preparatory to being still further reduced in the tube mills. The Griffin mill to be employed is a modification of the well-known American Griffin mill, is made by Mr. A. D. Griffin of Galt, and is known commercially as the "Senator."

The Belleville Portland Cement Co. A corner of the limestone deposits.

Two tube mills will complete the raw grinding, it being estimated that these will have a combined capacity equal to that part of the plant previously described.

The ground limestone and clay, at this stage reduced to a fine powder and intimately mixed, will be transferred by screw conveyor to the kiln room where the process of clinkering is to be carried out. This room is supplied at present with four rotary kilns, each sixty feet long and seven feet in diameter. They are set on a slight incline, and the material to be calcined will be fed in at the upper end, and the ground coal for fuel at the lower. As in the process of drying, the material, now white-hot clinker, will be discharged at the lower end of the kiln. Here it will be received into rotary coolers—one for each kiln. These coolers are analogous in construction to the rotary driers, and are similarly longitudinally divided, but are not lined in any way.

A feature of this plant is the method employed of utilizing the heat of the combustion gases from the rotary kilns. Adjacent to the upper end of each kiln is installed a 450-h. p. Babcock and Wilcox tubular boiler. The gases from the kiln prior to being discharged into the open air will pass down and through a brick arch and underneath the boiler. These gases will be at an estimated temperature of 2,000° F., and their surcharge of heat will be utilized to make steam for the development of the power for operating the plant. When necessary, the heating of these boilers may be supplemented by stoking. The designers estimate that seventy per cent. of the power required will be generated in this way. When it is remembered that the mere act of converting one pound of water at boiling temperature into steam at the same temperature requires 536 times as much heat as to raise a pound of water through one degree, it will be understood that the waste gases in any system of dry burning will be at a much higher temperature at exit than where fluid slurry is used. A recognition of this principle led to this method of using what would otherwise have been a great waste of energy.

Another exemplification of economy in design is the use of the heated air from the rotary coolers to produce the combustion of the ground coal in the rotary kilns. This air heated to a moderately high temperature through coming in contact with the white-hot clinker, will be drawn into the kilns, and this heat will be of assistance in producing the intense temperature required in the process of clinkering.

The clinker, after being discharged from the coolers, is conveyed to the grinding room, the final and raw grinding being accomplished under the same roof. The ground cement wlil be stored in a stock house 100 feet wide and 500 feet long, convenient for shipping either by boat or rail. Two docks, one for the unloading of coal, and the other for the shipping of the cement, have been constructed and afford a depth of seventeen feet of water.

The power equipment consists of a 600-h.p. Corliss tandem compound engine, made by the John Inglis Company, direct connected with an eight-inch line-shaft. This drives all the machinery in the mill room. In addition, there is a 400- k. w Westinghouse steam turbine direct connected to a generator which operates everything else. An emergency engine of 150-h. p. is also provided. The whole steam plant will be condensing, the water being supplied by centrifugal pumps. Individual motors are largely employed throughout the works. The management look forward to the utilization at some future time of the power of the Trent river. This power could be developed and transmitted electrically possibly at a less cost than steam at the works.

A fuel building has been erected. Griffin mills will be employed to grind the coal. The initial capacity will be one thousand barrels per day, but provision has been made for its ultimate increase to two thousand five hundred barrels by the addition of more machinery.

The Canadian Portland Cement Company, Limited

President .... E. Walter Rathbun, Deseronto.
Managing Director .... F. G. B. Allan, Deseronto.
Works .... Marlbank and Strathcona.
Brand ...."Star."
Capitalization .... $1,500,000.

Messrs. Rathbun & Co. were among the first to attempt the manufacture of Portland cement in Canada. Their first plant at Napanee Mills, now Strathcona, on the Bay of Quinte railway, manufactured natural cement from 1880 to 1897, the material being found in the Trenton limestone of that locality. The company's first experiments in the manufacture of Portland cement from marl were made about 1886, and were continued for five years at great expense before any very encouraging results were obtained. As a commercial enterprise in Ontario, this industry therefore really dates from 1891. At that time, the Rathbun Company had erected at Napanee Mills, three upright masonry kilns for the burning of Portland cement, the marl being obtained from Marlbank station, thirty miles from the plant. The clinker in those days was broken in jaw crushers and "edge runners," and received its final treatment in the buhr stones. These methods have been completely superseded in Ontario by others which have proven more economical and more efficient, but it must be granted that the well-nigh perfect processes now in vogue are the evolution of the defective methods of the pioneers in the industry, to whom for energy and perseverance, we of to-day owe a debt of gratitude.

A company organized under he title of the English Portland Cement Company, began the manufacture of Portland cement at Marlbank about 1891. In 1898 the Beaver Cement Company of Montreal, with capital furnished principally by Philadelphia people, took over this plant and operated it until 1900, when the Rathbun Company's interests were amalgamated with the Beaver Cement Company's, the result being the Canadian Portland Cement Company.

THE STRATHCONA PLANT

The Strathcona plant during the past year did nothing except grind a part of the clinker produced at the Marlbank works, and the probability is that its mixing and burning appliances will not again be called into requisition. A brief description of these may be read with interest.

The clay and marl were mixed in a rotary washmill thirty feet in diameter, ground in a tube mill and pumped to the storage vat twenty feet in diameter and eight feet deep, where the slurry was tested and adjusted. Part of this was then dried in three rotary Cummer driers, from which it was conveyed to the pug-mill. Here the dried slurry was mixed with sufficient wet slurry to produce a batter that could be made into bricks in the brick machine. These bricks were loaded on to cars provided with racks and pallets, and run into the drying tunnels. These tunnels are one hundred feet long and hot air was continually being drawn through them. The process of drying occupied two or three days, at the end of which time the cars were taken from the other end of the tunnels, and the bricks conveyed to the kilns. There are two continuous Dietsch kilns, two continuous Alborgs, and two intermittent bottle kilns. The fuel used for those of the first and second types was soft coal, but for the latter, coke exclusively was employed. The cement made in these bottle kilns was usually of excellent quality, and was of a peculiar bluish gray color, which formerly was generally regarded as superior and is still preferred by some. These kilns had a capacity of one hundred and twenty-five barrels each per burning, which was of three or four days' duration.

The grinding is now done in two ball and three tube mills installed in 1896. Power for this purpose is transmitted from the steam plant to the grinding building,

a distance of three hundred feet, by rope drive. The company has its own fire-fighting appliances, and maintains a laboratory where daily physical tests on the cement are made. The brand here as at Marlbank is "Star," but a silica cement is also manufactured. This is made by adding to the cement in the process of grinding a quantity of quartz sand, which is also subjected to abrasion in the tube mills The output at Strathcona is four hundred barrels per day.

The Canadian Portland Cement Co., Strathcona. The rectangular stack to the left is that of two Dietsch kilns. The two to the right belong to two Alborg kilns. The three low kilns in the foreground are of the intermittent "bottle" type.

THE MARLBANK PLANT

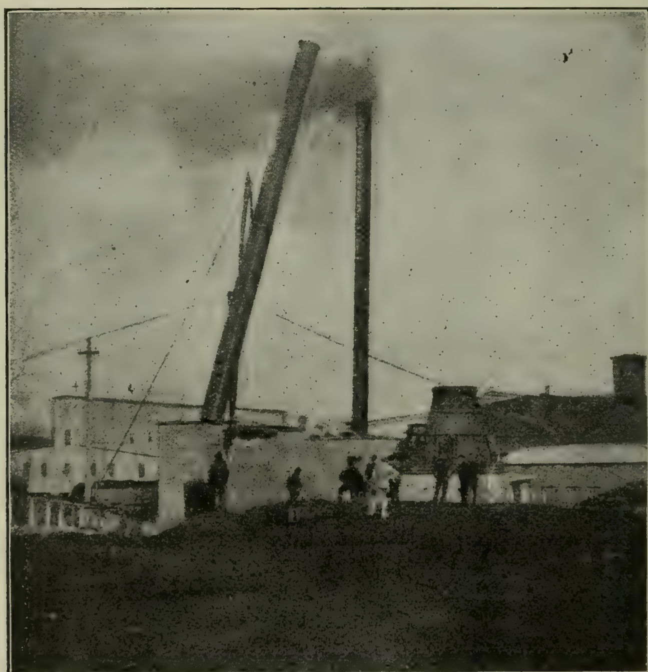
This modern plant is situated at the village of Marlbank, on the Bay of Quinte railway, twenty-five miles north of Strathcona. At present, its mixing and burning capacity is sufficient to keep employed the grinding plants at both Marlbank and Strathcona, the clinker being shipped from the former by rail.

Marl and clay are the raw materials and are at present obtained from Dry lake, adjacent to the works, the water having been lowered for the purpose. From ten to twenty feet of marl is found beneath the water, and below this in turn is the clay varying in depth from ten to twenty feet. A locomotive and train of cars is constantly employed in hauling the materials from the movable dredge to the works. In addition the company has two other very convenient sources of materials, namely, Lime lake and White lake, the latter comprising some eight hundred acres. It is safe to say that there is here sufficient material to last several hundreds of years at the present rate of consumption.

The marl and clay are dumped into the washmills, of which there are three—one for the clay and two for the marl. The ingredients work through gratings into chambers, from which they are pumped into measuring cylinders. Of these there are two, one for the clay and one for the marl. These empty into a common tank, from

which the supply for the raw grinding machine—tube mills and Sturtevant emery stones—is drawn. Following the grinding, the slurry is conveyed to receiving tanks, where it is tested, and if necessary, corrected by the addition of the constituent lacking. Pumping from these tanks to large steel or concrete storage tanks, ten in all, having a united capacity of two thousand five hundred barrels, where the mix is again tested, completes the preparation of the material. To prevent settlement of the heavier part of the mixture, air under a pressure of ninety lbs. per square inch is carried down vertical pipes to within a few inches of the bottom of the storage tanks. This keeps the slurry in a state of constant ebullition, and is found to be a most successful method of attaining an end much desired.

A floor trough with its axis perpendicular to the axes of the rotary kilns and almost directly beneath their high ends, receives its supply from any or all of the storage tanks as desired. A revolving "beater" running the entire length of the



The Canadian Portland Cement Co., Marlbank plant. In the little "bottle" kiln shown in this picture was manufactured the first Portland cement made in Canada.

trough prevents settlement of the slurry prior to its being pumped into the kilns. The pumps have adjustable crank pins, so that the length of stroke, and consequently the quantity of slurry pumped is under complete control.

The Marlbank plant has nine rotary kilns, four being ninety-five, and the remaining five sixty feet long. The longer ones on the whole give the better satisfaction, and of course have a much larger capacity per diem.

Ground coal is blown in at the lower end of the kilns, the speed of the kilns as well as the fuel supply being controlled by Mosser cone speed-regulators. The coal preparation plant consists of two forty-foot rotary driers, a Smidth ball mill and three tube mills in the order named. The clinker is elevated from the kilns and has its heat abstracted in four Mosser coolers, after which it is ready for the grinding room. Grinding is done in two No. 7 Smidth ball mills and a Smidth kominuter, the two being similar in principle. Tube mills complete the grinding of the cement, and a

is usual with these machines, they are lined with silex (flint) stone. The product from the preliminary grinding is admitted through the trunnion, and is discharged at the opposite end. A conveyor carries the finished cement underneath the Bay of Quinte switch to the storehouse on the opposite side.

The power required is supplied by a Wheelock tandem compound six hundred horse power condensing engine, two others of the same style of three hundred and fifty horse power each and an "Ideal" for electric lighting purposes. The plant is provided with a machine shop equipped with all machines necessary for making ordinary repairs, a brass foundry and a most complete laboratory and assay office. A library and comfortable reading room supplied with magazines and current literature is provided for the entertainment of the workmen. The capacity of the plant is one thousand three hundred and fifty barrels per day. "Star" cement enjoys a favorable reputation, and is marketed from coast to coast.

The Colonial Portland Cement Company

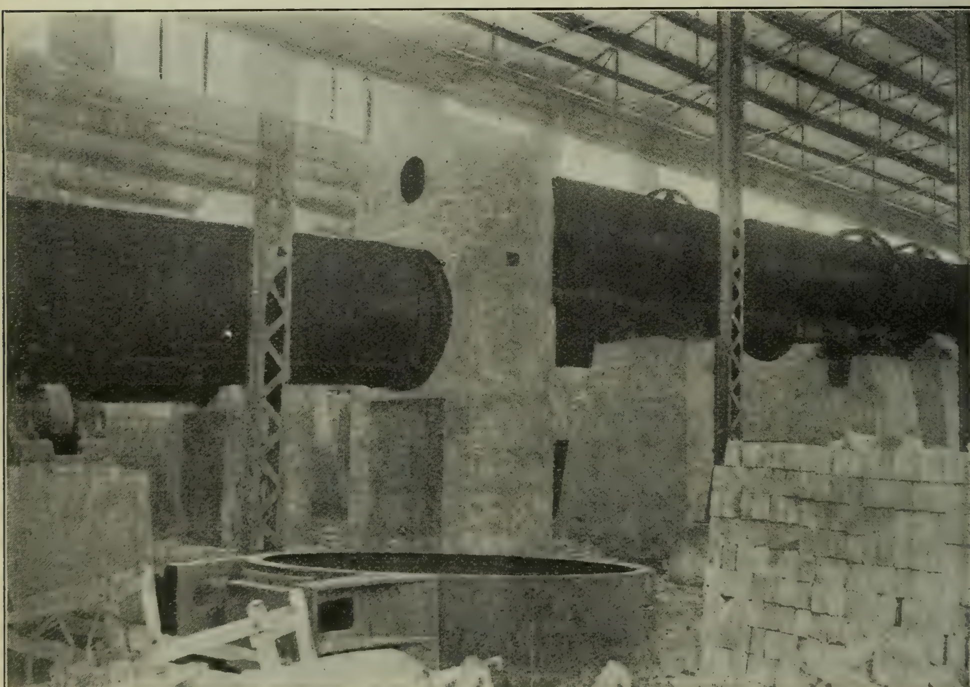
President ....Elbert L. Buell
Vice-President ....E. Young Jackson.
Secretary-Treasurer......... .... David A. Wright, Wiarton, Ont.
Authorized capital ....$800,000.
Works ....Wiarton.

General view, The Colonial Portland Cement Co., Wiarton.

The plant of the Colonial Portland Cement Company is located on Colpoy's bay on the outskirts of the picturesquely situated town of Wiarton, and is in a fair way to early completion. The Grand Trunk railway has extended its lines to the plant, and thus the company is in a position to ship by rail as well as by water. A shipping dock 800 feet long founded on piles and cribwork, and rendering available a depth of water of 14 feet has been constructed. This is provided with a tramway which runs from the boats to the mill.

The properties owned by the company which afford a supply of raw materials are in two separate localities. The first of these, portions of lots 9, 10 and 11, concession 22 and 23 of the township of Keppel, is but a mile and a half from the works. It is a marsh-like area, capable of easy drainage, and comprises one hundred and eighty-nine acres, with a depth of marl running to five feet. Clay underlies the marl. A growth of peat a few inches in thickness will necessitate a little preparatory surface stripping. A line of railway to connect this deposit with the works is in process of construction by the company. The gradient to the plant is falling throughout, thus facilitating the carriage of materials to the mill.

The second area available is known as lake Scales, and is four miles from the plant. This lake is extremely shallow, having less than two feet of water. The area is 205 acres, and the depth of marl is from five to twenty-seven feet. As in the



The Colonial Portland Cement Company. Rotary kiln. The lower portion is the kiln proper ; the upper is the dryer.

previous instance, a stratum of clay underlies the marl. This has a depth of two to eight feet. A survey of the lake has been made with a view to ascertaining the quantity of marl available. This has been estimated at four million cubic yards. In addition there is a quantity of shale obtainable from White Cloud island convenient to the works, which investigation has shown, will be extremely useful in the process of manufacture.

From a trestle work on the company's line, the raw materials can be dumped conveniently for handling at the beginning of the process. The marl will pass through Bonnat separators which remove stones and other *dèbris*. Then it will pass to a concrete storage pit. The shale if employed will be reduced in some form of crusher. After proportioning, the two materials will be mixed with the necessary quantity of water in Bonnot pug mills of four cubic yards capacity each, after which the mix will be transferred to storage pit number two. The separation of the ingredients is here prevented by rotary blade agitators. The raw grinding will be done in tube mills to

which the slurry will be pumped from the storage pit. From the tube mills it is discharged to storage pit number three, and is thence pumped into the storage tanks which supply the kilns. These storage tanks, of which there are three, are of concrete construction with external batter faces. The walls are reinforced peripherally by imbedding a series of strands of steel rods seven-eighths inch in diameter. The intention is to have one tank filling while a second is being corrected, and the remaining one is being drawn on for the kilns. Compressed air will be employed here to agitate the slurry.

The rotary kilns installed by the Colonial Cement Company present some features peculiar to themselves. The kilns are of a length over all of 105 feet, but are in two separate parts, each capable of its own independent motion. The upper portion into which the slurry is pumped from a transverse trench is known as the "drier" and is forty-five feet in length and five feet in diameter. A brick pier provided with an internal chute or incline leading from the lower end of the "drier" to the upper end of the kiln proper separates the two portions of the kiln. The result is that the axes of the two portions are not continuous the one with the other, but parallel, that of the kiln proper being slightly lower. The kiln proper is sixty feet long and seven feet in diameter. Four kilns are at present in place, and room for four others has been provided.

The clinker will be conveyed to Mosser tower coolers, from which the hot air is drawn by suitable fans and passed into the upper or drying portion of the kiln. Here it assists the gases from the kiln in the process of water expulsion. To further hasten the process of drying, a series of sections or tumblers have been riveted to the interior of the "drier." These will the better expose the fluid slurry to the action of the hot air and gases. It is estimated that the mix will be reduced to a twenty per cent. moisture condition when it leaves the drying portion of the kiln.

The clinker grinding apparatus has not yet been installed, but will probably be a battery of Griffin mills. Ground coal will be the fuel employed in the kilns, and an attempt will be made to instal a dust proof coal drying and grinding system.

Power will be supplied from three cross compound condensing engines of 400-h.p each. One will transmit to the dry grinding plant through a rope drive, and the other two will be direct connected with Fulter-Westrom Swedish generators. A battery of four Stirling water tube boilers made in Barberton, Ont., supplies the steam. Individual motors will be generally employed. The company's prospectus anticipates an ultimate output of one thousand barrels per day.

The Grey and Bruce Portland Cement Company

President	Jas. McLaughlin.
Vice-President	John Lind.
Secretary-Treasurer	A. D. Creasor, Owen Sound.
Authorized capital	$500,000.
Works	Brookholm, Ont.
Brand	"Hercules."

Like the Sun Portland Cement Company, the Grey and Bruce syndicate began manufacturing by the dry process. The change to the wet slurry system was made in September 1904, and has proved satisfactory, a more uniform mixing, and a better brand of cement being obtained. Further, under the old order of things, elevators were constantly getting choked with dust, and journals and other moving parts subjected to incessant wear.

Marl is obtained at Shallow lake, on the Harriston and Owen Sound branch of the Grand Trunk railway, some nine miles distant. At present, it is shovelled into flat cars, which are hauled in by the G. T. R., but the company contemplates putting in a dredge. Blue clay, obtained a quarter of a mile from the works, is blasted with

dynamite and teamed to the mill. The construction of a narrow gauge track from the works to the clay pit is another contemplated improvement.

The company have constructed a coal and shipping dock on the bay, and this together with suitable piers and elevated trestles facilitates the economical handling of raw materials, coal and the manufactured article.

From the elevated trestle the marl is conveyed in narrow gauge cars each of one cubic yard capacity, to the washmill. The clay is stored under a roof, and is weighed into the crusher, which in turn discharges into the washmill. In the opinion of the superintendent, however, quite as good results will be obtained without crushing the clay, and hence this part of the process may shortly be abandoned.

The washmill is of concrete, octagonal in form, and is supplied with three drags. The mix gradually works through a grating into a pit, from which it is elevated to two pairs of Sturtevant vertical emery stones. From here it is pumped to the storage tanks, four of steel and one of wood, which supply the kiln trough. This pump is a double cylinder one, and it is so arranged that pumping may be done into any one of the five. The slurry is tested when a tank is nearly full, and is not used until the mix is satisfactory. A tank of slurry can be corrected in the space of half an hour. Compressed air is used to agitate the slurry. The method of piping compressed air into the trough beneath the kilns has recently been abandoned in favor of a screw agitator. One of the three kilns is seventy feet long, the others being but sixty. These were supplied by the Vulcan Iron Works Company of Wilkesbarre, Pa., and by the Bonnot works. The speed of the kilns and the supply of ground coal are both controlled by Reeves' drives. The clinker is elevated from the kilns and conveyed to the clinker room, where it is allowed to cool in air. No mechanical cooler is employed.

The grinding is done in Krupp ball and tube mills. Before being admittted to the first of these mills, the clinker is weighed. The cement is finally conveyed to the stock room where the packing is done. The company ships in barrels, and in paper and cotton bags.

The coal is first crushed between rolls, passed through a rotary Cummer drier and then ground in a Griffin mill. Power for the plant is supplied by a 450-h. p. Jerome-Wheelock compound tandem engine, made by Goldie and McCulloch of Galt, and a 150-h. p. "Ideal" for electric lighting.

The company has purchased upwards of 400 acres of marl deposit, of which the upper seven feet are said to be of good quality. Below this, the quality seems to deteriorate. The result is that while a good grade of cement is possible from marl taken from greater depths, the expenses of manufacturing are considerably higher. Six acres of clay of a depth of fifty feet is the available supply at present. No surface stripping is necessary, although in the case of the marl, about one foot of peat has to be removed. The present output is 200 barrels per day, but with the addition of two more kilns and the necessary storage tanks and grinding machinery, the capacity will doubtless be doubled. The buildings are of limestone and brick. All machinery is supported on massive piers. A properly equipped laboratory is maintained, and a competent chemist employed.

Hanover Portland Cement Company

President and Managing Director	D Knechtel, Hanover, Ont.
Vice President	Jas. H. Adams, Hanover, Ont.
Secretary-Treasurer and Manager	Milton J. Müter, Hanover, Ont.
Authorized capital	$500,000.
Works	Hanover, Ont.
Brand	"Saugeen."

This company has been manufacturing Portland cement since the summer of 1898. The works are situated on the Saugeen river convenient to a waterfall which supplies a maximum of five hundred horse power during four months of the year

For the development of this a suitable power house has been erected. Two Samson turbines and a generator have been installed, and the power electrically transmitted to the works, a distance not exceeding a quarter of a mile. It has been found necessary to supplement the work of the turbines during the dry season, and for this purpose steam is employed.

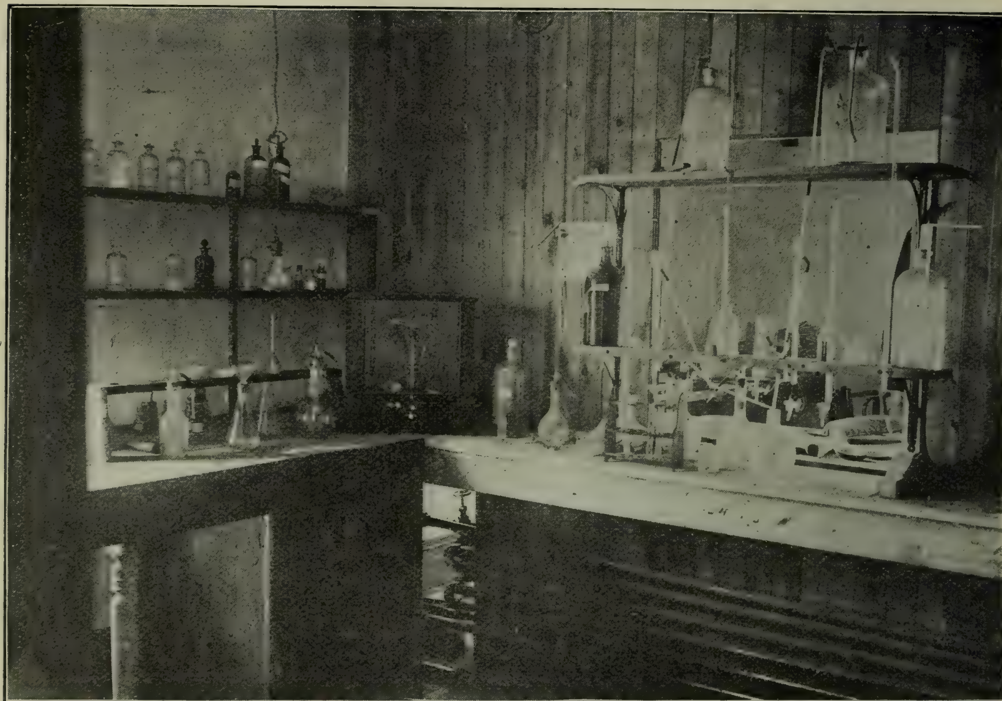
The Hanover Portland Cement Company. General view of works. The rectangular stack in the picture belongs to the Batchelor kilns.

In the township of Brant, a mile and a half from the works, are situated the company's marl deposits, comprising 150 acres of a depth of sixteen feet. The surface is covered with a growth of peat from six inches to a foot deep. Clay underlies the marl deposit, but is also found in the hill adjacent to the plant in sufficient quantity for the entire marl available. This supply is at present being used. The marl is raised by clam-shell dredge, filled into specially constructed dump cars, and hauled to the mill by a locomotive on a three-foot gauge track. The clay is filled into carts by hand and teamed to the mill, a distance of only a few hundred yards.

The marl is dumped in measured quantities from the track trestle into a wash-mill, into which the clay is also weighed. Following this, the grinding is done in emery stones and the slurry stored in two tanks each of one hundred and fifteen barrels capacity. Rotary stirrers in these tanks prevent the separation of the materials.

The burning is done in eight kilns of the Batchelor type elswhere described. The slurry is piped to the drying floors beneath the arches leading from the kilns to the stack, and when sufficiently dry is moved forward to the burning chamber by hand. The arches are 45 feet long and the interior diameter of the kiln proper is about nineteen feet. Twelve furnaces on an average are drawn per week from the eight kilns.

Grinding of the clinker is done in Smidth ball and tube mills, a jaw-crusher being employed for the preliminary reduction. A belt conveyor carries the finished cement to a store room of twenty thousand barrels' capacity. Packing is done entirely in bags. The outcrop of the plant is two hundred barrels per day.



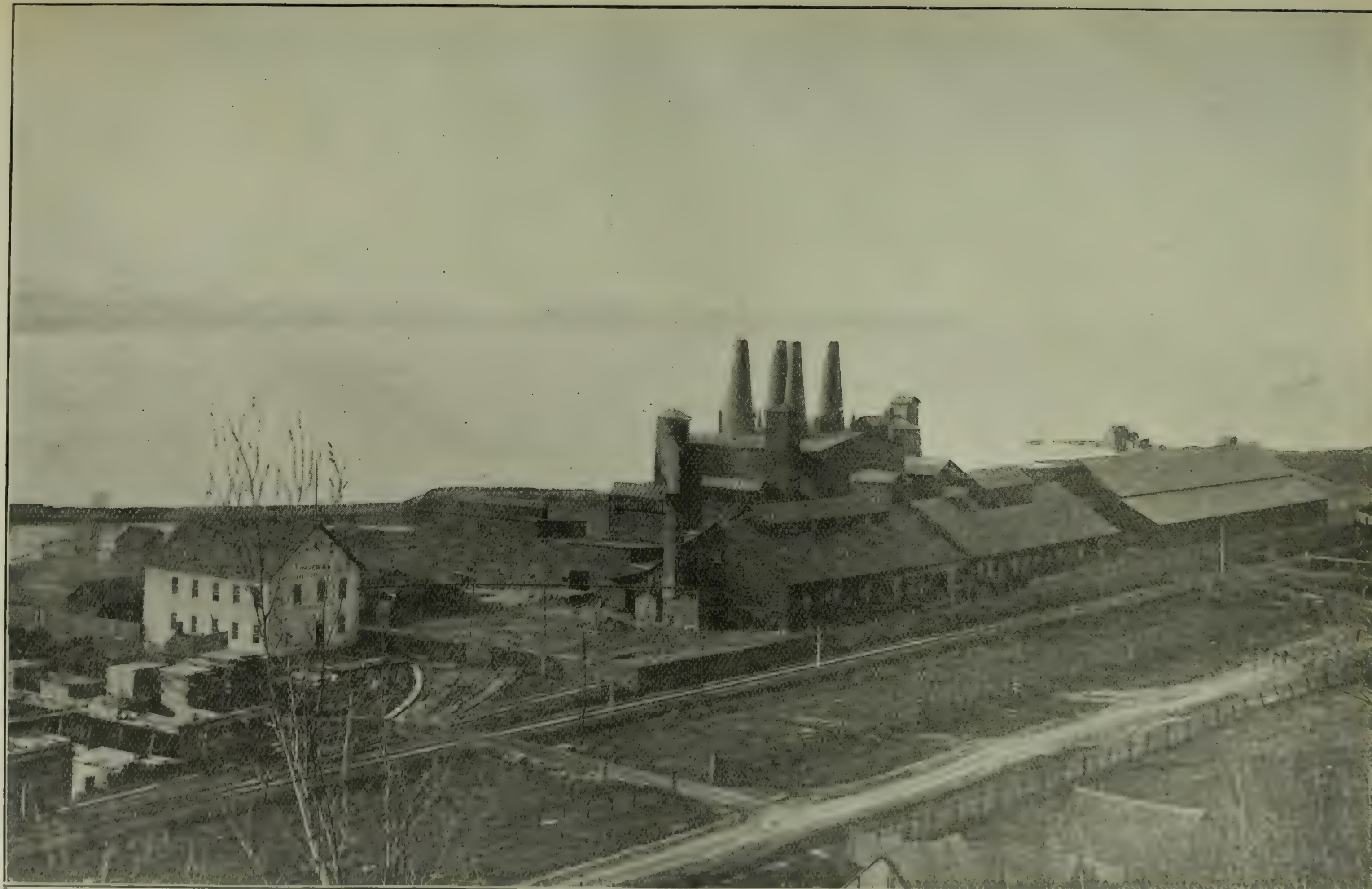
Hanover Portland Cement Co. The chemical laboratory.

The Imperial Portland Cement Company

President	M. Kennedy.
Secretary-Treasurer	J. W. Maitland, Owen Sound.
Authorized capital	$250,000.
Works	Owen Sound.
Brand	"Imperial."

The semi-wet method of mixing renders the process of making "Imperial" cement quite different from most of those at present in vogue in Ontario, though quite similar to that in use at Strathcona until a year ago. The clay is first passed between a pair of plain rolls driven at different speeds. Then it is dried in a rotary Ruggles machine, from which it is conveyed to the emery stones, which reduce it to a powder.

A Ruggles drier consists of two cylinders made of boiler plate, with a common axis, this axis as is usual with rotary driers being set on a slight incline. A furnace for the reception of the fuel—slacked coal in this instance—is provided beneath the lower end. The furnace gases pass down the inner tube, and are then admitted to the annular space between it and the outer one. They return by this passage to the stack immediately above the furnace, and in so doing come in contact with the material to be dried, which is admitted to this same passage from the upper end. Channel irons are rivetted to the outside of the inner cylinder and to the inside of the outer, and the revolving motion given to both insures to the material a thorough tossing and consequently, a pretty complete drying.



Imperial Cement Co., Owen Sound. The four conical stacks are those of the four Alborg kilns.

After grinding, the clay is stored in three tanks provided with hopper scales, by means of which it is weighed into the "mixing pan," into which the marl after being weighed is also dumped. This "mixing pan" is in the form of a shallow cylinder and has a vertical centre shaft. This shaft carries two horizontal arms constituting virtually a diameter of the so-called pan. The extremity of each arm is the axle of a ponderous wheel or roller which through the rotary motion of the upright shaft is made to take a circular path also around the bottom of the pan.

Part of the mix from the pan goes through a second Ruggles drier, the rest going at once to the pug mill, and from it to the brick machine. The object of drying a portion only is to enable the operators by mixing the dried material, with the undried to secure any desired plasticity at the exit from the pug mill. The brick machine is provided with an expression screw and a nozzle measuring ten inches by four and a half inches. From this nozzle a constant "stream" of stiff mortar-like slurry is delivered to a carrying belt. An operator with a wire "cutter" chops this "stream" into bricks four or five inches wide. These bricks are then loaded by hand on cars having suitable frames which are run into drying tunnels one hundred feet long. Of these, there are fourteen. Each tunnel can accommodate fifteen cars. Here the bricks for some thirty hours are exposed to a blast of hot air supplied by two forty-eight inch fans. At the end of this time they are quite dry, and the cars are run out and elevated with their load of bricks to the charging floor of the Alborg kilns. There are four of these kilns, and from the highest floor the bricks are charged into the furnace. On the next floor the stoking is done. The burning takes place largely below these fire-holes, and the cooling below this in turn.

The clinker is drawn from below four times in twenty-four hours.

The grinding of the clinker is done in Smidth ball and tube mills. Packing is done in bags and barrels by hand. The capacity of the plant is three hundred barrels per day, and the cement is marketed chiefly in Ontario and the Canadian west.

The marl is obtained from Williams lake, in Holland township, a distance of thirteen miles from the plant. The area is one hundred acres, and the depth exceeds thirty feet on the average. It is brought to the works by the Canadian Pacific railway. Both red and blue clay are used, the former being a quarter of a mile from the works and the latter across the bay, on which the company has constructed a good shipping dock. In this latter place there is a deposit of one hundred acres in extent.

The management are contemplating some radical changes in the plant with a view to adopting the wet system of mixing.

The International Portland Cement Company

President ....W. F. Cowham.
Vice-President .... A. F. MacLaren, M. P., Stratford.
Secretary ....P. W. Stanhope, Toronto.
Treasurer ....D. Jamieson, M. D., Durham.
Authorized capital .... $1,000,000.
Works ....Hull, Que.

Though not situated in Ontario, being just across the Ottawa river at Hull, in the Province of Quebec, these works, at present in process of erection, are largely owned by men interested in cement manufacture in Ontario, and when completed, will be the largest in Canada. Like the Belleville plant, this one will use limestone instead of marl, both it and the clay being obtained in practically the same place. The company has acquired an area of over four hundred acres, three hundred of which is limestone sixty feet in depth, the remaining being clay. The limestone is said to be remarkably uniform in composition at all depths, varying scarcely more than one per cent. in lime content.

The plant is being erected on the shore of lake Leamy, near the city of Hull, which without much cutting can be connected by navigable canals with the Gatineau and Ottawa rivers.

A unique feature of the equipment is the method to be adopted in bringing the raw materials from the quarry and clay beds to the works. Huge wooden towers have been erected, two at the raw material buildings and other two at points where the limestone and clay can be loaded for transportation to the plant. Stout cables have been stretched from top to top of these towers, and from the cables cars will be swung. The raw materials will thus be rapidly and cheaply transported to the mill. The span between the towers for the limestone is sixteen hundred feet, and between those for the clay, eleven hundred.

The clay will be first passed through a disintegrator, and thence conveyed by inclined belt upward to two rotary driers sixty feet by six. By a screw conveyor, it will pass to an edge runner, and by elevator to the clay storage room, a building 110 by 56 feet, and having a capacity of seven thousand tons, equal to four months' consumption. This storage room has a tunnel underneath into which sixteen hoppers from the room above can discharge. In this way, clay from any part of the building may be drawn on for the daily needs of the kilns, the supply for which is always taken from below by screw conveyors located in the tunnel. Measuring hoppers constructed on a telescopic principle so that their capacity may be altered as desired are employed here to measure volumetrically the clay prior to its being admitted to the Gates tube mills. The output of these tube mills will be of sufficient fineness to pass ninety-five per cent. through a number one hundred sieve. The material will be next elevated to hoppers which feed the rotary kilns.

The limestone will be brought to the mill by a device identical with that by which the clay is to be handled. A large Gates' crusher will first reduce the rock to a 1½-inch size, after which it will be sorted in a revolving screen; that which is rejected by the screen will go through a second Gates' crusher, after which it and the finer size from the first crusher will be conveyed to the stone storage room. The crushers are to be driven by individual electrical motors.

The stone storage room is of design similar to that of the clay storage room, and has the same style of drawing tunnel underneath. A bucket conveyor completely surrounds the room, passing through the tunnel underneath. A "tripper" at the roof is mounted on a track so that the stone can be discharged wherever desired. Surface water on the stone running to perhaps 1½ per cent. is removed by rotary driers similar to these employed to dry the clay. After being dried, the limestone will be conveyed to hoppers, which in turn will feed the Krupp ball mills which are to reduce the stone to 20-mesh. This grinding will be completed in the tube mills.

The burning will be done in a battery of eight rotary kilns each sixty feet long. Provision will be made to utilize the heat from the rotaries in warming the buildings. The clinker will be cooled by drawing a blast of air over it after it drops from the rotary kilns. The heat thus evolved will be employed in drying the coal.

The clinker grinding will be done in ball mills and tube mills. Most complete arrangements for handling the clinker, for transporting to and from the grinding machines, and for storing and packing the finished product, are being made. The total floor space will be three and a half acres. The buildings are of a most substantial character, the foundations being concrete, and the walls up to ten feet from the ground being artificial stone. Expanded metal is largely employed for the upper portions of the walls and for the roofs.

Coal for fuel in the rotaries, as stated above, is first dried, then crushed, and finally ground in tube mills. The store room for crushed coal is 200 feet by 48 feet, and has a very complete type of continuous conveyor that can be used either for filling or emptying.

Power will be obtained from one of the Hull water power companies at the low price of $15 per horse power per year. This is a factor which will no doubt contribute to the economical operation of the plant. In addition to this, the company has purchased the water rights and lands necessary for the development of a fine water

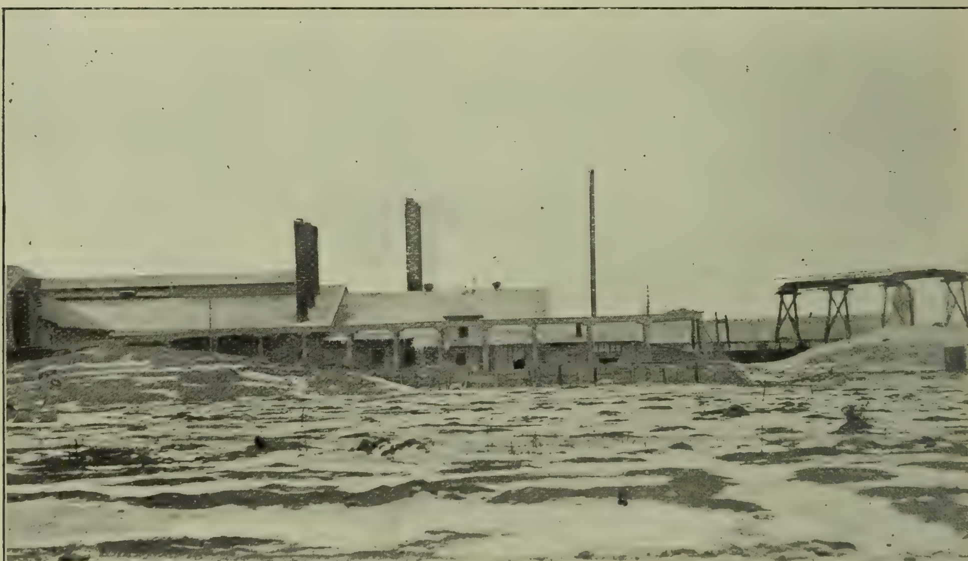
power on the Gatineau, known as the Cascades. It is said that at low water over 14,000 horse power are here available, and that the expenses of development will not be excessive.

Regarding shipping facilities, the prospectus of the company has this to say: "The two raw materials lie side by side and distinctly separate from each other at the connection of the Canadian Pacific railway, the Canada Atlantic railway, the New York and Ottawa railway, the Ottawa and Prescott railway, the Northern and Western railway, the Rideau canal, and the Gatineau and Ottawa rivers."

The company expect to begin manufacturing operations during the summer of 1905.

The Lakefield Portland Cement Company

President	**J. M. Kilbourn.**
Vice-President	**R. P. Butchart.**
Secretary-Treasurer	F. A. Kilbourn, Lakefield, Ont.
Authorized capital	$1,000,000.
Works	Lakefield, Ont.
Brand	"Monarch."



The Lakefield Portland Cement Co., Lakefield. General view of plant.

The Lakefield Portland Cement Company, Limited, began manufacturing on the 2nd day of January 1902. For the purpose of getting access to some eight hundred acres of submerged marl in the township of Douro, the company drained Buckley's lake, which is one and a half miles from the village of Lakefield, the site of the works. The marl is transported this distance in the company's own steel dump cars, hauled by its own locomotives over its own railroad. Clay is obtained from Lily lake in the township of Smith, on the Midland division of the Grand Trunk railway. It covers an area of twenty acres and varies in depth from five to fifteen feet.

Excavation from both deposits in carried on by means of immense steam-operated hydraulic elevators, which, plying on a track of fourteen feet gauge, are self-propelling and lift, carry and lay their own track in thirty-feet sections. Each will load, under favorable conditions, a thirty-ton flat car in seven minutes. The marl averages nine feet in depth, but reaches twenty feet in places.

In a single rotary washmill, the raw materials are given their preliminary mixing. This mill consists of a cylindrical basin eighteen feet in diameter, provided with two feeding chutes, one for marl and one for clay at opposite sides. The former is measured by volume; the latter by weight. The basin is provided with a vertical centre shaft that carries horizontal arms to which heavy "drags" are attached. The shaft is made to revolve and the mixing of the two materials is thus more or less completely accomplished. To secure a still more perfect incorporation of the two ingredients, the mix is passed through emery grinding stones and thence to tube mills. Unlike many others, these mills are lined with wooden blocks sawn to the proper arc, which may be easily removed and replaced by others when worn. Six cylindrical concrete and six wooden storage vats receive the slurry after the raw grinding is completed, the method being to test and correct the mix in each before admitting to the kiln pumps. It is so arranged that any one tank ar any number of tanks may be receiving slurry at any time, while the supply for the rotary kilns is drawn only from those in which the mixture is known to be correct. Sufficient slurry for forty-eight hours' burning may be easily stored here.

As in another plant previously described, a trough transverse to the axes of the kilns receives the slurry from the storage tanks. The method of agitating by compressed air is employed here, as it is in the storage tanks, and is reported as being eminently efficient.

Pumps supply the rotaries, of which there are six, three being sixty feet and three one hundred feet long. The former revolve at the rate of sixty revolutions per minute, and the latter at about forty. The upper ten feet of the length of each kiln has large channel irons rivetted on the inside of the kiln longitudinally. These serve by tossing the semi-fluid slurry, the better to expose it to the hot gases, and assist in the expulsion of the water. The shorter kilns are said to give the better satisfaction. The usual methods of controlling speed, feed of slurry and of ground coal to the kilns are employed here.

The kilns discharge into a horizontal conveyer, and the clinker is ultimately elevated and admitted to rotary cylindrical coolers. These are provided also with channel irons rivetted to the inside of the cylinder. Cool air is drawn through these coolers, and after taking up the heat of the clinker, is delivered by blower to the ground coal kiln feeders.

The grinding of the clinker is accomplished by ball and tube mills, both Krupp and Bonnot makes being employed.

Slaked coal is dried in a revolving drier, and then pulverized in Raymond vertical mills.

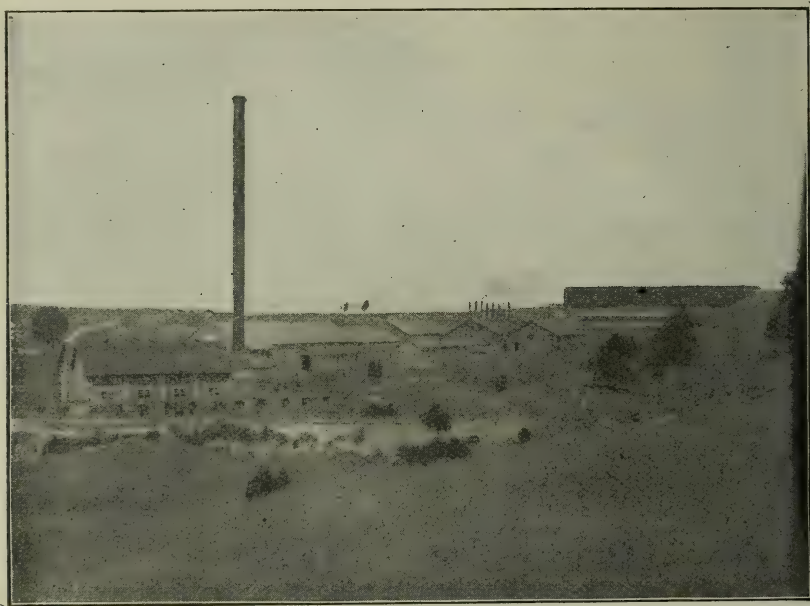
Power is obtained from lock No. 3 of the Peterborough-Lakefield section of the Trent canal, three miles distant, and also from Young's Point, five miles from the plant. Generators are provided at each place, and the electrical energy wired to the place of consumption. These powers are constructed to operate jointly or singly, and either is capable of carrying on the work of manufacture, so that a "shut-down" of the works on account of lack of power is never feared.

The output is between six hundred and seven hundred barrels per day. Export of cement and importation of coal for fuel are as yet almost wholly by rail, but the completion of the Trent canal will undoubtedly mean the utilization of water for both purposes to a very great extent.

The National Portland Cement Company

President	W. F. Cowham.
Vice-President	A. F. MacLaren, M. P.
Superintendent	H. H. Farr, Durham, Ont.
Authorized capital	$1,000,000.
Works	Durham, Ont.
Brand	"National."

The National Portland Cement Company began the manufacture of cement early in 1903. The works stand at the bottom of a rather steep declivity, and the railway supplying the raw materials is continued from the plateau on a level steel trestle over the storage rooms, thus facilitating the unloading very materially.



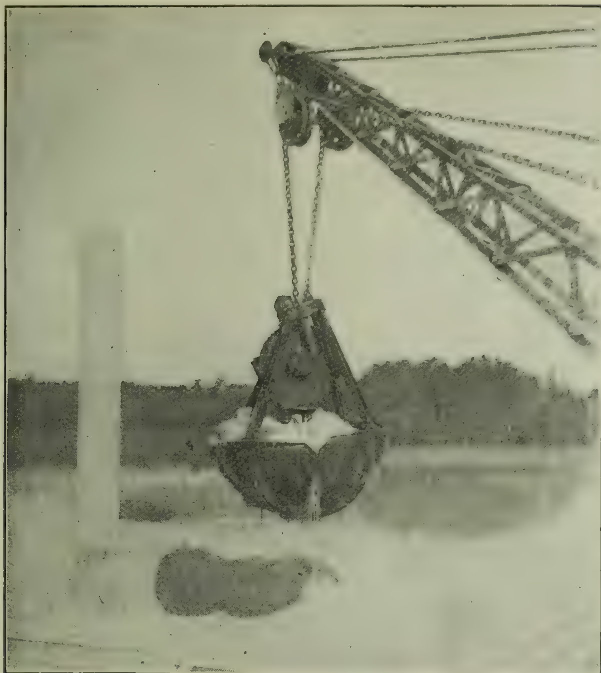
National Portland Cement Co., Durham. General view of works.

Wilder's lake, five and a half miles from Durham, and Tobermory lake in the same neighborhood, are the sources of the marl. The former has an area of 125 acres, and the deposit varies in depth from two to fifty feet. The latter is but fifty acres in extent. The overlying water is of a depth of twelve feet in places, and beneath this is an average of twenty-five feet of marl. Clay is brought from Stratford, a distance of sixty-nine miles, and is hauled to the works on flat cars. Of this, the company has acquired a deposit of forty acres.

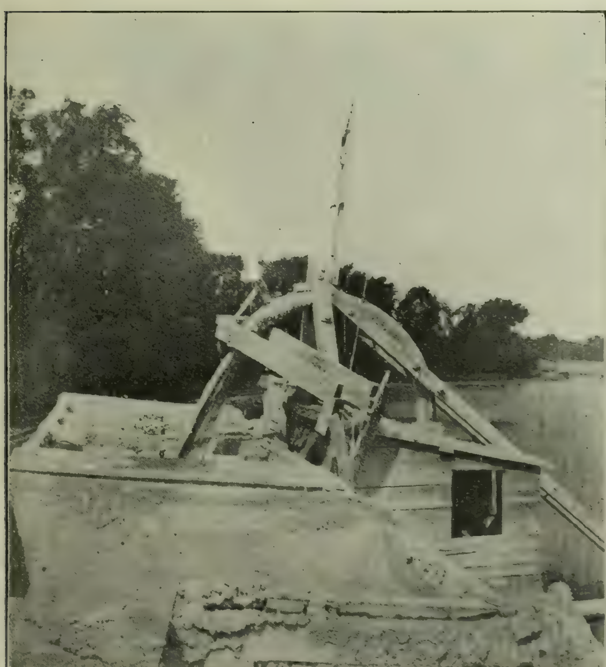
The marl is raised by floating dredge with an orange-peel dipper. This dredge is equipped with a stone separator and a pug-mill.

After passing through these machines the marl is conveyed through a flexible tube carried on a series of pontoons to the hopper-shaped cars on shore. The "Harris" system of conveying by compressed air is here employed, and is said to work to the utmost satisfaction.

The clay is fed into a plain rolls disintegrator, and after passing through a cylindrical rotary drier 50 feet long and five feet in diameter, is conveyed to a Phillips and McLaren dry pan. This consists of a pan containing a pair of huge upright wheel-like "molars" similar in construction to the at one time familiar "edge-runners." The pan has a moveable meshed bottom, so that the size of openings can be altered from three-eighths to five-eighths of an inch. The pan is made to revolve while the axis of the molars retains its fixed position. The clay is thus pressed through the meshes and reduced to the desired size. It is then fed to a cenveyor and passes to the dry clay storage room 100 by 60 fet. Here the chemist takes samples for analysis every hour of the twenty-four.



National Portland Cement Company. Orange peel dipper.



National Portland Cement Company. The Harris pneumatic system of pumping marl.

Running longitudinally with the dry clay storage room and beneath its centre line is an underground arched tunnel, carrying a bucket conveyor. The roof of the arch is provided with hopper-like openings, which may be opened or closed at pleasure. The dry clay may thus be drawn from any part of this building and transferred to the wet department. It has been the practice of the company to store during the open season a quantity of clay for winter consumption, and for this purpose a large wet storage room from which the drying plant is conveniently supplied, has been erected. The dry clay is delivered to the mixing pug mill by measuring hoppers, each of about 600 pounds capacity.

The marl is brought in on the high level trestle above referred to and dumped into a hopper of two cars capacity, which supplies the marl pug mill. From here it is conveyed to a battery of nine marl storage tanks, at the bottom of each of which a series of pipes delivers compressed air through bent nozzles. This imparts to the fluid a swirling boiling motion completely preventing settlement. These tanks stand on a series of step-like piers that gravity may assist the flow of marl to the "mixing pug mill," where the marl and clay first come together. The tanks are further supplied with floats, enabling the operator in accordance with the chemist's instructions, to draw any depth of fluid marl to mix with a known quantity of clay. The output of the mixing pug mill is automatically transferred by the Harris compressed air devices to the tube mills, of which there are four. It is then transferred by the same method to eight steel slurry tanks. From an open "header," supplied by compressed air from these tanks, the kilns are fed. A revolving disc carrying a number of buckets which alternately fill from the header and discharge into the tube supplying the kiln, accomplishes this step. The speed of the disc varies with that of the kiln.

There are eight rotary kilns 70 by 6 feet, which are capable of being run at different speeds. The clinker drops into pits built beneath the kilns. Here it gives up a portion of its heat to air, which is in turn mown with the ground coal into the rotaries. The clinker then passes by chute into the water-tight buckets of a McCausland conveyor, which is at this point moving horizontally in a bath of water rising nearly but not quite to the edge of the pans. This conveyor completely surrounds the clinker storage room, passing through a tunnel underneath, up a vertical shaft at one end, along the roof and down again at the other end. A movable tripping device at the roof is so arranged that clinker may be emptied at any point desired. Further, there are hopper-shaped openings in the roof of the tunnel, so that clinker may be drawn from any part of the building. In this way, when the conveyor is not bringing fresh clinker to the room, it is feeding cold clinker into the hoppers supplying the ball and tube mills. The necessary quantity of gypsum is added after the material comes from the ball mills, and before it goes to the tube mills.

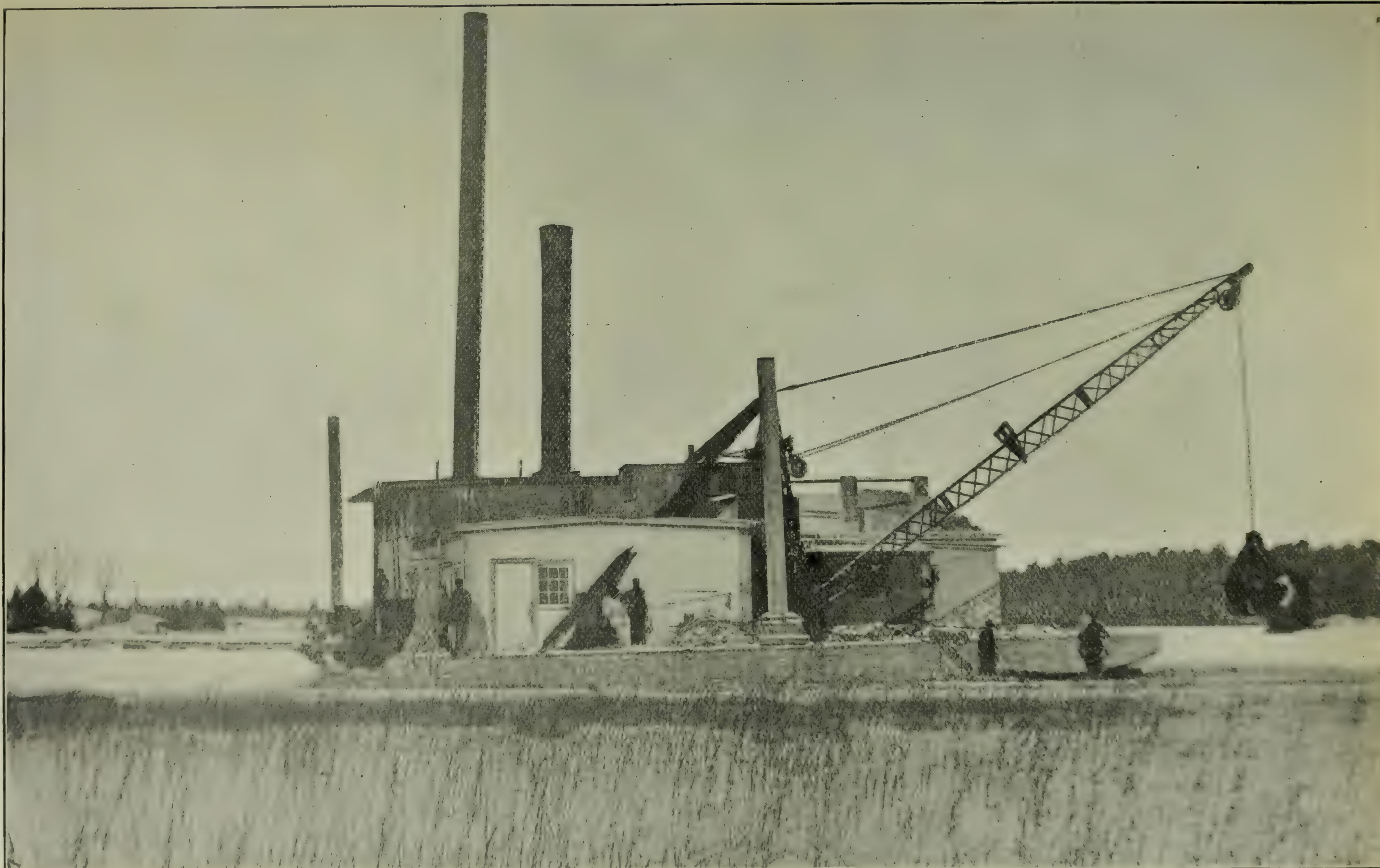
A belt conveyor carries the cement to the store room, and a tripping device similar in its purpose to the one previously described, is employed to fill any one of the eighteen bins in which the cement is stored.

Packing is done by three automatic machines of five hundred barrels each per day. Bags are employed almost exclusively, eighty-seven and a half pounds constituting a bag, and four bags being the equivalent of a barrel of three hundred and fifty pounds. The capacity of the plant is one thousand barrels per day. Ontario and he Canadian west absorb the output.

Coal for fuel for the rotary kilns is dried in rotary driers and reduced to a flour in improved Griffin mills. The power house is equipped with suitable engines and generators, driving by individual motors being the method generally adopted throughout the plant.

A most complete laboratory equipped with all the requisite appliances for making analyses and tests is maintained, and is in charge of Mr. S. H. Ludlow, a specialist in the chemistry of cements.

This plant, which undoubtedly is representative of the best modern practice, was designed by W. B. Bogardus of Cornell, N. Y.



National Portland Cement Co., Durham. Dredge equipped with Harris' pneumatic system of pumping marl.

The Ontario Portland Cement Company

President ....E. L. Goold.
Vice-President ....W. S. Wisner.
Secretary-Treasurer ....E. D. Taylor, Brantford, Ont.
Authorized capital ....$450,000.
Works ....Blue Lake, Ont.
Brand ...."Giant."

Blue lake is about three miles from the town of Paris, and is reached therefrom by electric railway. The plant stands on the shore of the lake, and at present the marl is being obtained not 600 feet from the works, to which it is brought in dump cars by locomotive. There are in this one deposit 100 acres running all the way from thirty-five to fifty feet in depth. A dredge will shortly be installed to supplant the present method of raising by manual labor. Fifty acres of clay of a depth of ten to twenty feet are available in one deposit beyond the lake. It is brought in by cars as is the marl.

In the process of mixing, the wash mill is employed. As is usual in such cases, the marl is measured and the clay weighed. The mix passes from the mill through a grating to a large rotary double agitator. A well adjoining receives the slurry from which by a large duplex pump it is conveyed to a hopper, above the tube mill.

After the process of grinding it is collected in two large concrete storage tanks reinforced by expanded metal. Compressed air is employed in these tanks to keep the slurry in a state of constant ebullition. Before being admitted into the supply trough, the contents of each kiln are checked by titration and corrected by the addition of whatever constituent is lacking. Three rotary kilns 70 by 6 feet are at present in use, but the management contemplate considerable additions to the plant. The velocity of the rotaries is controlled by a speeder, which is operated by the man in charge of the kilns. If the clinker should be discharged from the kilns insufficiently burned, the feed of slurry or the speed of the rotary can be reduced.

From the kilns the clinker is wheeled to the clinker room to cool. No special device to accomplish this is employed. The grinding is done in Krupp ball and tube mills, after which the cement passes to the stock house which is provided with eight bins of three thousand barrels capacity each. These are built on the "cribbing" plan, commonly exemplified in the construction of grain elevators. Power is conveyed to the coal-grinding plant from the power house by rope drive.

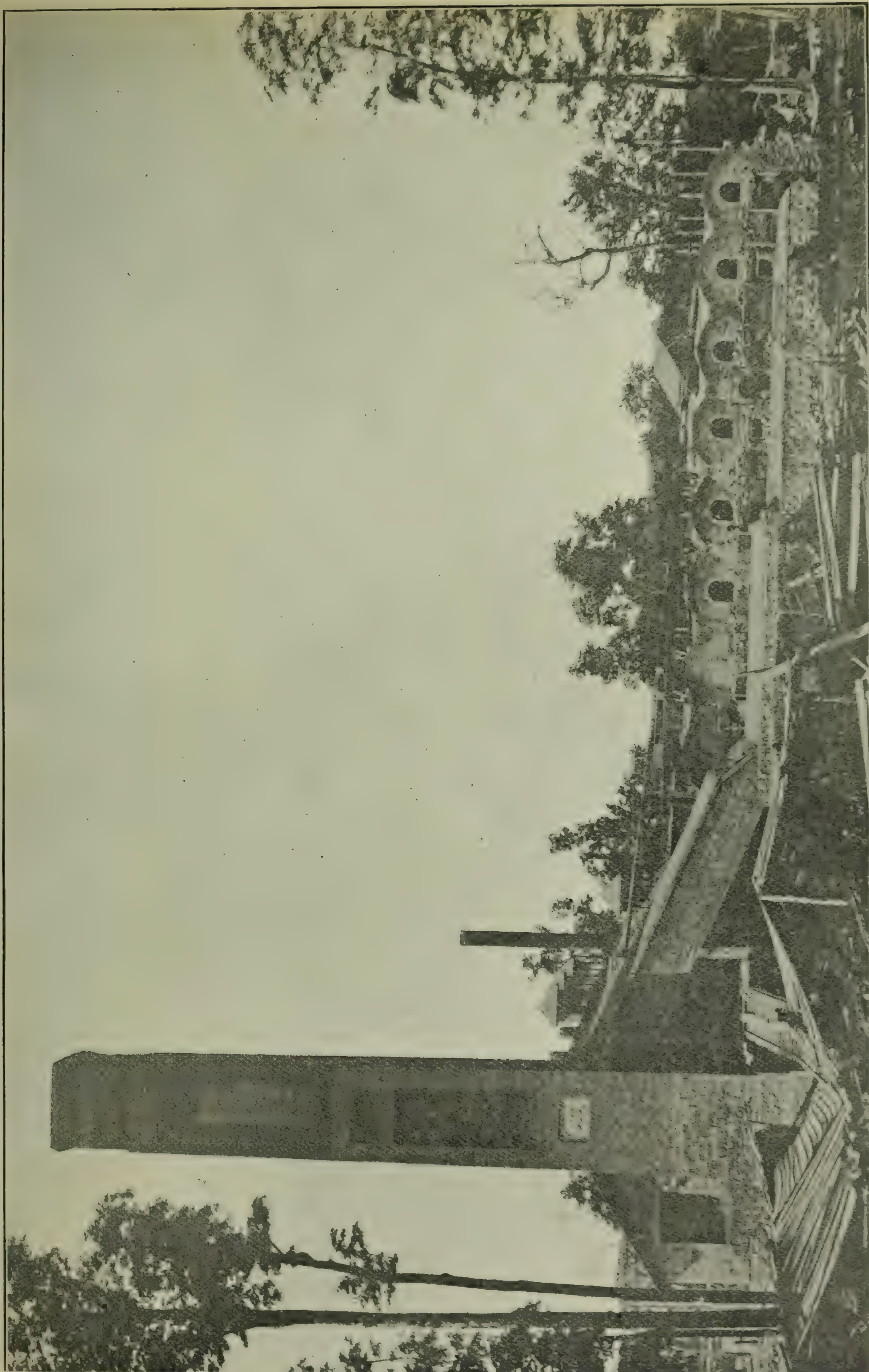
Coal for fuel is stored in bins under cover until required. Prior to grinding in the tube mill, it passes through a rotary Cummer drier.

The company has two shipping connections in the Grand Valley Electric railroad and the Grand Trunk railway, each of which has a spur running to the works. The former of these is owned by the company. The present output is 450 barrels per day, but will be increased this coming summer to 750 by corresponding additions to the plant. "Giant" cement seems to be well received, and the directorate report the demand for their product to be very good.

The buildings are of brick, steel and Redcliffe corrugated iron, and are as nearly fireproof as possible. The company has its own fire appliances. Boarding houses, workmen's cottages and laboratory have also been erected by the company. The post office of Blue lake is for the present in the company's office.

The Owen Sound Portland Cement Company

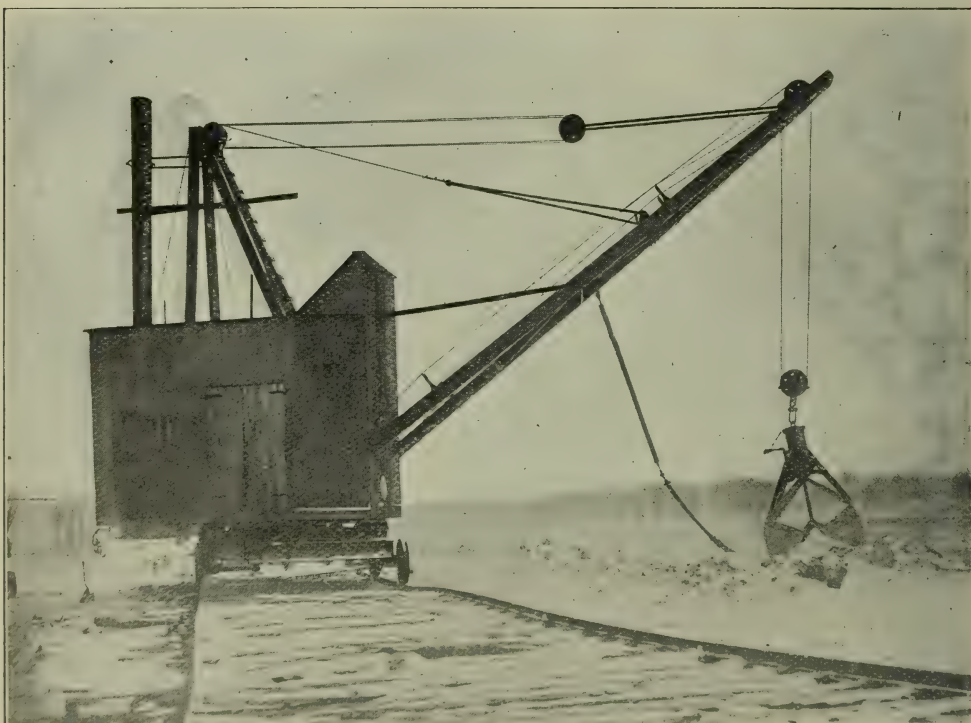
President ....J. E. Murphy.
Vice-President ....W. H. Pearson.
Secretary-Treasurer ....G. S. Kilbourn.
Works ....Shallow Lake.
Brand ...."Samson."



Owen Sound Portland Cement Company, Shallow Lake. Eight Batchelor kilns.

Away back in 1889, The North American Chemical, Mining and Manufacturing Company was organized at Owen Sound for the purpose of manufacturing Portland cement. Its capital was $100,000. A large building of masonry walls was constructed at Shallow lake in that year, and a plant subsequently installed. A Ransome cylinder was used in which to burn the cement, but proved unsatisfactory, and was abandoned, This industry was the forerunner of the Owen Sound Portland Cement Company, which to-day carries on a very extensive manufcaturing business.

Shallow lake occupies lots 6, 7, 8 and part of 9 in the seventh concession of the township of Keppel. The area is nearly 600 acres, including several small islands, and about 500 acres are under water for half of the year. "Two streams flow into the lake and in the dry season they unite near the works on the northern side, the channel continuing about 800 yards farther in a northwesterly direction towards the margin of the lake, where the waters disappear with a loud rumbling noise through a series of sinkholes in the bottom." The bottom of the lake is covered with marl to a depth of four feet, underneath which lies clay running to ten feet in places. A narrow gauge



The Owen Sound Portland Cement Co. Marl and clay dredge.

track has been constructed from the works out into the lake, and a locomotive and train of cars are employed to bring the clay and marl from the steam dredge to the plant. A contract was lately entered into with the James Cooper Company to erect tall towers and equip a system of cable transportation for the raw materials, but the new method has not yet been put into working shape.

The ingredients are mixed in a rotary washmill, the clay having been first put through a disintegrator. A Ferris wheel is used to elevate the slurry to a pair of Sturtevant emery stones. Nine large storage tanks have been constructed, into which the material is next pumped and in which it is agitated by compressed air.

The burning is done in nine Batchelor kilns, each having two drying arches, and in two rotary kilns each 100 feet long. These rotaries were originally 65 feet long, and the additional 35 feet were added to act as a drier for the slurry. They have a capacity of 120 barrels each per day. The Batchelor kilns are intermittent, it being the usual custom to get 14 kilns of clinker from the 9 furnaces each week. They are charged with alternate layers of dried slurry and coke, there being a 10-inch layer of the former to a 3-inch layer of the latter.

The clinker from the Batchelor kilns is first crushed before going to the ball and tube mills; that from the rotaries is first passed through a rotary cooler. The final grinding plant consists of two Krupp ball mills and three tube mills. The output of the plant is 700 barrels per day.

Ground coal is used for fuel, this being dried and ground in a Raymond grinder and in emery stones.

The power plant comprises an Inglis Brown 500-h. p. engine, a Corliss compound 350-h. p. engine, an air compressor made by the Rand Drill Company of Sherbrooke, Que., and a battery of five boilers. The company has its own fire protection plant, its own blacksmith and repair shop, and an extremely tidy office and laboratory made of cement blocks—a striking exemplification of the use of the article which the company manufactures. The management propose doubling the capacity of the works this present year. "Samson" cement is favorably known from coast to coast.

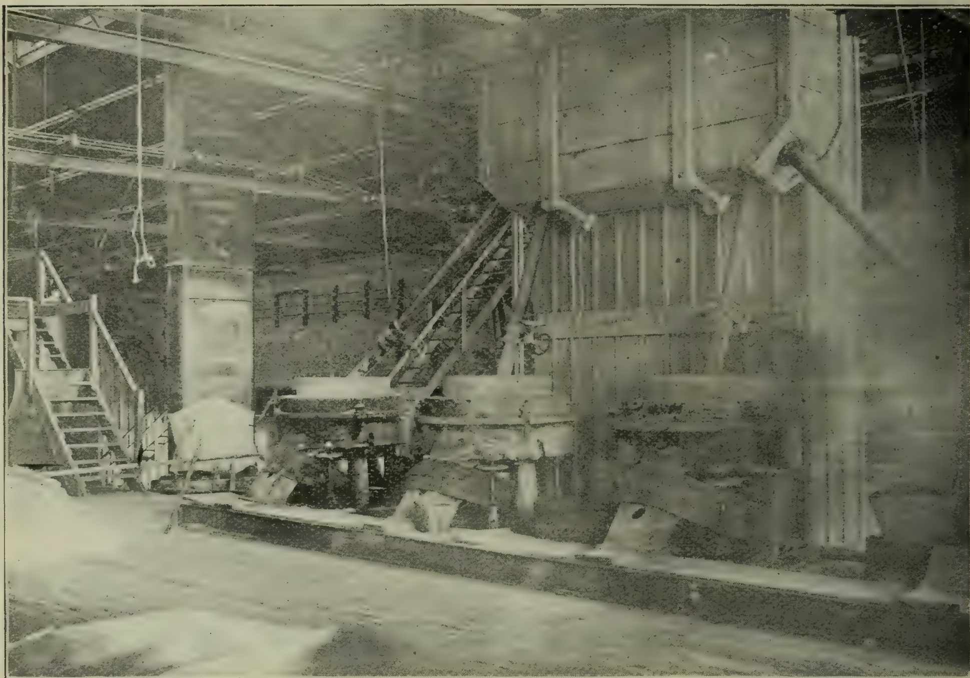
The Raven Lake Portland Cement Company

President	Gideon Shortreed.
Vice-President	Thos. F. White.
Secretary-Treasurer	Thos. McLaughlin.
Authorized capital	$500,000.
Works	Raven Lake, Ont.
Brand	"Raven."

The Raven Lake Portland Cement Company gets its name from the shallow lake from which its supply of marl is obtained, and on the shore of which its mills have been erected. Raven lake is situated on the Lindsay-Coboconk branch of the Grand Trunk railway, about two miles from Victoria Road station, and eighty-three from the city of Toronto.

From Elliot's falls on the Gull river, fifteen miles distant, the power necessary to operate the plant is electrically transmitted. A government dam has been constructed there which gives an available head of twenty-two or twenty-three feet, and in a series of small lakes farther up stream ample pondage facilities are provided.

The marl, which extends to a depth of twenty feet, is elevated from the lake bottom by means of a floating dredge and orange-peel dipper. This dredge is equipped with an air-compressor. As in the Durham plant previously described, the marl goes through a stone separator prior to being admitted to the Harris pneumatic pumping apparatus, which by compressed air conveys the marl to shore through a flexible pipe eight inches in diameter. This flexible pipe line connects the dredge and the raw material department in the mill, and is supported on a series of floating pontoons, each consisting of four coal oil barrels secured together by a suitable frame. The marl if not sufficiently fluid may be brought to the correct condition for piping by the addition of water. The pipe discharges into a huge marl storage tank. From this, the marl is admitted at pleasure to the mixer where it unites with the clay. The clay is at present obtained near Beaverton, and is brought thither on flat cars a distance of fifteen miles. It is first dried in a rotary drier, then ground in rotary emery stones, and finally elevated to weighing hoppers which empty, as does the marl, into the mixing washmill.



The Raven Lake Portland Cement Company. A battery of Sturtevant emery stones for raw grinding, etc.

Raven Lake Portland Cement Company, Raven Lake. General view of Works, etc.

Four slurry storage tanks are provided to which the mix is conveyed, and in which the contents are agitated by compressed air. The slurry grinding is accomplished in a battery of four Sturtevant individually electrically driven emery wheels.

The rotary kilns, of which there are four, may be considered as being divided each into two parts—a rotary drier and a kiln proper. These two parts are not continuous in alignment, but the former lies above the latter, their axes being in the same vertical plane. The slurry is admitted to the high end of the drier and is discharged from its lower end. Then it passes through grinding rolls, and is conveyed into the upper end of the kiln proper, in which the clinkering process takes place. The driers are forty-eight feet long and five feet in diameter, the kiln proper being 60 by 6 feet. An air current through the drier is secured by a rotary fan. The hot air from the kiln is made to pass through the drier and thus what would otherwise be waste heat is utilized.

The clinker is first cooled in a Wentz patent upright cylindrical cooler, then crushed in a Kent rolls mill and receives its final grinding in tube mills. The hot air from the cooler passes up the same chute as the one down which the clinker falls and goes into the kiln, thus effecting an economy in fuel.

Ground coal is used for fuel, the processes in its preparation being crushing, drying and grinding, first in rolls and then in tube mills.

The buildings are of limestone walls, with roofs of corrugated steel, supported on steel frames. The capacity of the plant will be four hundred barrels per day.

The Sun Portland Cement Company

President	W. P. Telford, M. P.
Secretary-Treasurer	John Armstrong, Owen Sound.
Authorized capital	$500,000.
Works	Owen Sound, Ont.
Brand	"Sun."

By means of two towers with cable connection, and a clam-shell dipper, the marl required in the process of manufacture of "Sun" cement is unloaded from cars and transferred either to the marl heap or to a hopper which supplies through a chain conveyor, the marl washmill. The clay is brought in by teams, passes first through a plain rolls disintegrator, and thence by conveyor to the clay washmill. These two mills are adjacent and each supplies by a chute its contents to a large double agitator. This in plan suggests a huge 8. About the centre of each segment, a set of "drags" is made to revolve on a vertical shaft. The mixture is next ground in emery stones and then pumped into four storage tanks where the examination and correction of the slurry takes place. Each tank will contain seven hours' run, and any one can be drawn on as desired. A floor pit connected with each tank next receives the slurry, and from this pit it is pumped to the kilns, of which there are four, two being sixty and two sixty-five feet long. The clinker drops into pits beneath the floor, is elevated to a Mosser cooler and passes by conveyor to the grinding room. This room is supplied with one Krupp ball mill and two Gates' tube mills. A screw conveyor and elevator belt transfer the finished cement to the stock room, where packing is done. The coal grinding plant consists of a rotary drier and a tube mill.

A 650-h. p. Goldie and McCulloch Wheelock tandem condensing engine, and a 100-h. p. "Ideal" furnish the necessary power for operations of plant and lifting respectively.

The marl is obtained at lake McNab in the township of Keppel, on the Harriston and Owen Sound branch of the Grand Trunk railway, some twelve miles from the works. A private spur was constructed to the lake from a point two miles distant. This marl area comprises 460 acres running from fourteen to twenty-five feet in depth. A steam shovel is employed to raise the marl.

Clay is obtained from the village of Brookholm in the township of Sarawak, at a distance of only one mile from the plant. The capacity of the works is 350 barrels holm per day. "Sun" cement is marketed largely in Western Ontario and Western Canada.

Shipping facilities for the export of the finished product and the importation of coal by water are particularly good. The company has its own docks and coal derricks adjacent to the mill. Coal is imported by water direct from Cleveland.

"Sun" cement was first made in 1902. Then the dry process was used, but this proving unsatisfactory, owing to the tendency of the clay to "ball" in masses, the wet process was introduced. Manufacturing by this method was begun in July, 1904.

The Sun Portland Cement Co. A corner in the assaying laboratory.

The Superior Portland Cement Company

President	B. E. McKenzie, M. D.
Vice-Presidents	Thos. McCarty and W. Howard Jackson.
Secretary-Treasurer	Geo. McIntyre, Orangeville.
Authorized capital	$500,000.
Works	Orangeville, Ont.
Brand	"Superior."

Three hundred and sixty acres of marl in the township of Caledon, Peel county, from twelve to thirty feet in depth and one hundred acres of clay in the township of Garafraxa, of an average depth of eight feet, will give some idea of the extent of material available for cement purposes by this company.

The mill stands but a stone's throw from the Canadian Pacific railway station at Orangeville. It is intended to lift the materials by steam shovel, and bring them to the works by railway. The clay will come nine miles by the C. P. R., and the marl on the company's own railroad, a distance of two and five-eighths miles. A layer of two feet of peat overlies the marl deposit.

Prior to passing into large concrete octagonal wash mills, the clay will be put through a disintegrator. It and the marl will then be sent down chutes to the two wash mills as stated, which will be provided with gratings at one side. Through these gratings the mixture will gradually wash and be conducted to an elevator sump, thence to emery mills and a tube mill, which will complete the raw grinding. Three large wooden storage tanks will be provided in which the correction of the mixture will be made. These tanks will be agitated by compressed air.

Foundations for three rotary kilns eighty feet long and seven feet in diameter are already laid, and ultimately the company will install three additional kilns. Clinker pits, one for every two rotaries, will be provided at the discharge ends of the

Superior Portland Cement Company, Orangeville. Main building.

kilns. Elevators will convey from these pits to the rotary coolers. Two ball mills and two tube mills will easily handle the immediate output of the kilns, but another ball mill and an extra tube mill will have to be added when the complete battery of six kilns is in operation. Griffin mills will probably be employed to grind the coal.

The mixing, burning and grinding building is two hundred and ninety-seven by eighty feet. The coal house is one hundred and six by forty-three feet, and the stock house one hundred by seventy-five. In addition, there is a power house which will be supplied with engines capable of generating one thousand horse power. Electrical generator and motors for individual driving will be features of the equipment. The tracks at the works will be elevated twelve feet on a trestle, so that the materials and coal can be dumped from the cars directly into the works. The capacity of the completed plant will be six hundred barrels of cement per day. The company expect to have their brand on the market during the coming summer.

There is a possibility that in the early future the Cataract water power on the Credit river may be employed to generate energy which can be transmitted by wire to the works at Orangeville. It is said that the falls in the river gorge at the place referred to afford a head of nearly two hundred feet.

The Western Ontario Portland Cement Company

President ....A. S. Langrill, M. D.
Secretary-Treasurer .... J. A. Mitchell, Atwood, Ont.
Manager .... M. M. Hiles.
Authorized capital .... $500,000.
Works ....Atwood, Ont.

This company was incorporated under Provincial charter in the summer of 1903 and proposes to manufacture Portland cement from clay and marl, both of which are found convenient to the village of Atwood, in deposits of considerable extent. The marl will be obtained five miles south of the village, the site of the plant, in the township of Elma, from an ancient lake bottom now a marsh. The area is 250 acres. There is an overlying layer of peat from two to five feet in thickness, which the company hopes ultimately to utilize as a source of fuel. The installation of suitable drying and compacting machinery is a part of the general scheme, and in view of recent improvements in peat fuel manufacture, the possibility of success will be granted. The marl underneath this peat growth is from eighteen inches to twelve feet in thickness, and analyses show this to be of very good quality. Beneath the marl in turn is found the clay running to a depth of thirty feet.

A second area of equal extent is also held by the company. This deposit lies five miles west of the site of the works in the townships of Grey and Elma. This, however, will probably not be worked for some time, as the first mentioned beds will supply enough raw materials for many years at the estimated output.

The process will be the wet slurry method, and for this suitable mill buildings are being erected and plant installed. Six rotaries are to be employed with an estimated capacity of six hundred barrels of cement per day.

The clay and marl are to be raised by steam shovel, and will be transported to the works over a standard gauge track for which the steel was supplied by the Grand Trunk Railway Company. The company will have the option of buying this road outright at the end of ten years. It is expected that the town of Atwood will assist the enterprise by granting a free mill site and exemption from taxes for a period of 20 years. The company expect to have their product on the market in October of this year.

NATURAL CEMENT

Natural cement, as stated elsewhere, is produced by burning an impure limestone. In Ontario, it is found in certain parts of the Trenton and Niagara formations.

An analysis reveals the presence of lime, magnesia and clay in more or less definite proportions. In nearly all natural cement quarries, the stone appears in strata. Analyses almost invariably show that the composition of the rock varies with the depth, the tendency being for the calcium carbonate to be in maximum proportion at the upper stratum, and the clay ingredients a maximum at the lower. Let us suppose a case where there is an excess of the lime constituent in the upper layers and an excess of clay in the lower, the mean of both giving about the correct proportion for a good cement. Now if rock be taken indiscriminately from the quarry, burnt and ground, it will be seen that an analysis would no doubt indicate that the two ingredients were present in about the correct proportions, while it would be equally true that evidences of both over-claying and over-liming might be detected in the

finished product. The thorough mixing would be accomplished in the grinding, yet it would be impossible that the clay and lime of adjacent fragments in the kiln could unite chemically in a way essential to a good cement. The difficulty in securing a constant and intimate mixture is one respect in which the natural cement is less likely to develop the strength for which good Portland has acquired a reputation.

Both natural and Portland cements have their uses, and the answer as to which is desirable in any instance will depend on the strength required, on the allowable time for setting, on whether or not the cement is to be laid under water, and on the cost. If no great strength is required, and a rapid setting mortar is desirable, natural cement can be employed at a less cost than Portland. The time of setting, however, is exceedingly variable in both natural and Portland cements. The former usually begins to set in five to forty minutes, and attains its permanent set in twenty minutes to two and a half hours. Portland, on the other hand, begins to set in three-fourths of an hour to three hours, and attains its final set in two and a half to eight hours.

The question of relative cost is worthy of a little consideration, and the following is given for the purpose of comparing in a typical case, the cost of two mortars intended to give the same strength.

Suppose a cement mortar for foundations, piers or walls is required which will develop say 200 pounds per square inch ultimate tensile strength in three months. Most Portland cement mortars mixed in the proportion of one of cement to five of sand by volume, will attain this strength in the time stated, while a natural cement mortar for the same specification would require to be mixed in about the ratio of one of cement to two of sand. Let us assume the price of sand to be about $1,25 per cubic yard, that of natural cement to be $0.90 per barrel, and that of Portland to be $2.50 per barrel. In explanation, it should be said that the voids in the sand and its shrinkage on the addition of water will render the volume of the resulting mortar very little in excess of that of the sand as first measured. In both cases following, the mass of mortar would in an average case be about one cubic yard.

Portland Cement Mortar 1 : 5				Natural Cement Mortar 1 : 2			
.9 cubic yards sand	@ $1.25	=	$1.12	.8 cubic yards sand	@ $1.25	=	$1.00
1.2 bbls. cement	@ 2.50	=	3.00	2.5 bbls. cement	@ 90	=	2.25
Cost per cubic yard			$4.12	Cost per cubic yard			$3 25

It is thus seen that the natural cement mortar is 87 cents cheaper per cubic yard than a Portland cement mortar of anticipated equivalent strength. This conclusion of course obtains only under the conditions assumed. The relative cost would be influenced by a variation in the cost of the two cements and of the sand, by the quantity of water used, and by the voids in the sand. Our Ontario natural cements are slow-setting, and of course none of them develop the early tensile strength either neat or in mortar of the Portlands.

The producers of natural cement in Ontario are Isaac Usher & Sons, Queenston, the Estate of John Battle, Thorold; F. Schwendiman, Hamilton; and the Toronto Lime Company, Limehouse.

Queenston Cement Works

The Queenston Cement Works are situated in the township of Niagara on the Queenston and Grimsby stone road. They are but two miles from the historic village of Queenston, made famous nearly a century ago through the heroic exploits of Sir Isaac Brock, Laura Secord and others in the defense of Canada.

The plant stands on a sheer precipice one hundred and eighty-five feet in height. The well-known "Queenston blue" Niagara limestone used extensively for building purposes is here 22 feet deep. Beneath it is found the cement rock 6 or 7 feet in

thickness, and beneath this in turn is a gray sandstone. Mr. Usher is the lessee of a property somewhat exceeding 450 acres, only 15 of which have been mined.

Drifting was begun from the base of the old limestone quarry, from which a great deal of the material for the masonry in the first Welland canal was obtained. The cement rock is quarried with the assistance of steam and air rock-drills and explosives. A track has been laid and by means of cars the stone is hauled to the feeding hoppers of the kilns, which are on a slightly lower level than the bottom of the cement rock stratum. Pillars of rock are left at intervals of about 30 feet to support the limestone overhead. No timbering has been found necessary, and in twenty years, no accident to any workman has occurred. The mine has perfect ventilation.

There are eight upright masonry continuous draw-kilns, each thirty-two feet in height and eight feet in diameter. They are fed from above with alternate layers of stone and coal, and at any time there are about twelve feet of fire in a kiln. The lower portion is styled the cooler and the upper the forewarmer. A cord of cement stone makes twenty-two barrels of cement.

The coal is delivered from a switch on the Grand Trunk railway, and is dumped on the same level as the firing hopper of the kilns. A kiln is drawn four times in twenty-four hours. Experienced men sort the burnt stone, and any parts not sufficiently burned are returned to the kilns. The properly calcined stone passes down a chute to the "cracker" and from there to a steel-plate grinder, in which it is reduced to the size of wheat. Buhr stones or Sophia mill stones complete the grinding. A gravity screen here rejects any portions incompletely ground and returns them to the stones, but whatever is sufficiently reduced goes down another level to the store room. It is thus seen that gravity assists very considerably in the handling of the material. A spur of the Niagara branch of the Michigan Central railway runs between the packing and store houses, so that shipping by rail is rendered extremely convenient.

The output of the plant is at present 350 barrels per day, and additions and improvements, especially in the quarrying and grinding, are soon to be made.

"Queenston" cement is employed chiefly for floors, foundations, silos, dwellings and farm use generally, and is marketed in Western Ontario and Manitoba. A small export is annually made to Lewiston and other towns in the vicinity, in New York state.

The Estate of John Battle

The works of this company are in the town of Thorold. In 1841 Mr. John Brown, the predecessor of the late John Battle, opened the quarries from which the cement rock is now obtained. There is a surface layer of fourteen feet of clay overlying an equal thickness of crystalline limestone. Beneath this is found the cement stone, varying in thickness from eight to ten feet, and of tolerably uniform quality. The stone is mined both in the open cut and in drifts underneath the overlying limestone, the roof being supported as in the Queenston mine on pillars of either the stone itself or of built-up materials. The location has an area of 50 acres.

From the quarries, the rock is brought by narrow gauge track and horse cars to a battery of five upright continuous kilns, where the burning is done by filling alternate layers of soft coal and stone. Four days after the fire is begun, "drawing off" is commenced, and is repeated at intervals of twenty-four hours continuously afterwards. The usual care in the selection of proprely burned rock and the rejection of cinder, slag and underburned stone is then necessary. The calcined stone is brought by the Niagara, St. Catharines and Toronto Electric Railway to the mills in the town of Thorold, one mile from the kilns, power for the purpose being obtained from the old canal, where a head of fourteen feet is available. Two turbines of eighty and sixty horse power respectively, supply the necessary energy.

The stone is first broken in a "cracker," and then ground in buhr stones of which the mill has three run. Bagging in cotton and paper is done from spouts connected with the receiving bins. The output of "Thorold" cement is 200 barrels per day, and

reaches about thirty thousand barrels per year. The present proprietors are the sons of the late John Battle, who assumed control of the works at least thirty years ago.

F. Schwendiman

The quarry from which Mr. Schwendiman obtains his cement rock is situated in the township of Barton, four miles from Hamilton. The rock at present is being obtained from the valley of a small stream. It is burned in a continuous fire-brick lined upright kiln, and reduced by a "cracker" of the coffee mill type, and by buhr stones, of which the mill has two run. The kiln has a vertical height exceeding 20 feet and a maximum diameter of about eight feet. The stone is carted up an incline to the top of the kiln where a receiving hopper has been constructed. The throat of the kiln is just below the hopper, and is about five feet in diameter. The firing is done in two burning arches on opposite sides of the kiln. These arches are about six feet in length—the thickness of the walls of the structure. Soft coal is the fuel employed. The burned stone is drawn off beneath through an inclined chute and is wheeled by barrows to the grinding mill. The plant has a capacity of 65 barrels per day. It is marketed from Rymal station, a short distance from the quarry.

Toronto Lime Company

The Limehouse cement works are situated on the main line of the Grand Trunk railway, where the road makes the ascent of the Niagara escarpment. The formation is the same as at Thorold, being at the base of the Niagara limestone.

The Toronto Lime Co., Limehouse. View of kiln for making natural cement.

The company manufactures lime extensively, this industry of late years much surpassing in importance the manufacture of natural cement. The Gowdy kilns in which the cement is made are situated at Limehouse. The limestone has been quarried from the surface for building and for the manufacture of lime over an area of twelve acres. Under this to a thickness of nine feet lies the cement rock. The location covers an area of nearly forty acres. On account of the well marked stratification, the quarrying is attended by no great difficulties.

The kiln is similar in construction to the one at Hamilton just described. The height over all is thirty-five feet, the throat at the top being eight by ten feet. There are four fire holes, two on each side of two opposite sides, into which the stoking is done. The "Eldridge" system of blowing is employed. A rotary fan draws hot gases from a point seven feet below the top of the kiln, and this hot air is forced by the same fan into the fire-place. By a suitable contrivance any quantity of cold air may be admitted to the blast to mix with the hot. The manager states that the most desirable fuel for the calcination of natural cement limestone, is wood. Coal is said to give too intense a heat, and the object of the Eldridge system is to moderate this heat by the introduction of carbonic acid gas into the blast. The method is said to work very satisfactorily. The kiln is lined with fire-brick, and this lining has to be renewed once every three years.

The kiln is drawn once every four hours, and the stone allowed to cool an hour on the floor before being removed by cart to the mill to be ground. The "cracker" reduces to pea size, after which the buhr stones complete the reduction. The capacity of the plant is 100 barrels per day. Packing is done in barrels of 240 pounds capacity, and in bags of half that quantity. The brand is known as "Ontario."

TESTING OF CEMENTS

A perfect method of testing cement has yet to devised. A uniform method—or rather a method which with uniform material will give uniform results in the hands of all experienced operators—has also yet to be invented. Many attempts to secure such results by complicated and expensive testing machines have been made, and in some cases at least the results obtained were less satisfactory than where the simpler method was used. It should be and is possible to employ a few simple tests—requiring but inexpensive equipment and reasonably sure in results, that will discover a good cement and expose the pernicious qualities in a bad one. For the general user, this should be sufficient. The tests that are usually made are six in number, and are as follows: fineness of grinding, specific gravity, tensile strength, neat and with sand, the hot test and the time of setting.

Fineness of Grinding

It has been observed that fine grinding will decrease the tensile strength neat, but will increase it in a mortar. As no cements are used commercially without some kind of aggregate, the latter is the phase of the result to which the user's attention is directed. Fineness is not a sure indication of the value of a cement, although all cements are improved by fine grinding. The residue on sieves of various sized mesh, usually fifty, one hundred and two hundred to the lineal inch, is expressed as a percentage of the original weight. In the results printed elsewhere, one thousand units by weight of cement were sifted by hand. Sifting was discontinued when after a certain time interval a quantity less than one unit—one-tenth of one per cent.—passed the sieve. Sieves of fifty and one hundred meshes to the linear inch were employed in this instance. A "trace" may be interpreted as a quantity less than one-tenth of one per cent. of the original.

Specific Gravity

The specific gravity test is considered to be a means of detecting under-burning, over-burning or adulteration. Cement being a powder susceptible to the action of water, coal oil or turpentine is usually employed in the determination. Care should

be taken that no change of temperature in the fluid takes place during the experiment, and that no bubbles of air are concealed in the flask. An overburned fused clinker will give a heavy cement, while an underburned one is likely to be low in specific gravity. Adulterants are usually of less density than cements, and will operate to reduce the specific gravity.

Tensile Strength

The tensile strength test, rightly or wrongly, has come to be the one to which the popular eye is directed in judging the merits of a brand of cement. This test, if properly made, is without doubt a valuable though not a perfect indication of quality. The cement is made into a stiff batter and placed in briquette moulds of a least cross-section of one square inch. After setting for twenty-four hours in moist air, the briquettes are removed from the moulds and placed in a water bath where they remain for times varying very much at the caprice of the tester. These periods, however, are usually three days, seven days, twenty-eight days, and three, six, or twelve months. At the end of the interval desired, they are broken in some kind of tensile testing machine. A good cement should show an increasing tensile strength as the age become greater. If there is a dropping off in ultimate strength at the longer time tests, it would lead us to suspect that under-burning or over-liming was the fault. Either of these will give what we have come to call "free lime." This "free lime" through spontaneous disintegration, will in time reduce the tensile strength.

In the experiments, whose results are given elsewhere, the percentage of water necessary to give a proper consistency was found in each instance by a preliminary test. That percentage, when learned, was used in the subsequent tests with that brand. The water used was first brought to roo mtemperature (608 F.) and a regular interval of three minutes' trowelling on the slab was given each batter before placing in the moulds.

Experience has shown that the ratio of compressive to tensile strength varies from seven to ten in mortar in the proportion of one of cement to three of sand, and as the latter is much more easily obtained, it is almost exclusively employed, notwithstanding the fact that cement in sructures is not usually subjected to tensile stress. Experience has further shown that the personal element is a matter of great consequence in the making of tensile tests of cement. This is true to a very great extent in mortar tests, and in a lesser degree with neat cement also. The manner and duration of the mixing and the method of compacting in the mould would undoubtedly influence the results obtained in no small degree. For this reason it is scarcely fair to compare one man's results with another's, or perhaps even with his own, unless through extensive experience he has acquired a methed of working that is nearly uniform. Were we to take a parcel of cement thoroughly mixed so that the quality is uniform throughout, and divide it into five parts, giving each of five experienced testers a sample, with instructions to determine the tensile strength of a three to one mortar, we would very probably be surprised at the discrepancy in results. The so-called "personal equation" must be reckoned with when an attempt is made to institute comparisons.

The mortar tests were made from a three to one mixture for Portlands, and a one to one for natural cements. The sand used was a calcareous pit variety, free from organic matter, loam or clay. The briquettes were lightly rammed with a steel rammer, and every attempt to do this in a uniform manner was made. The proportions were by weight, not volume.

Constancy of Volume

It has become the fashion to consider the hot test, a test for free lime, which in the presence of heat and moisture slacks and disintegrates the pat. This may or may not be so, but it is certain that free lime, if added to a good cement, will produce the "blowing" which it is the purpose of the hot test to detect. In the test of Ontario brands, the pats were allowed to stand six hours in moist air above a

bath of water kept at 120° F. Then they were put in the hot bath for the remaining eighteen of the twenty-four hours. Pats made of good cement should not leave the glass plate, should not crack or disintegrate in any way, and if broken should snap with a moderately high musical note. A cement that stands the hot test and is finely ground, is not likely to give very much trouble.

Setting

The setting is usually reported at two stages — initial and final. Initial set is defined as the interval elapsing from the time of adding the water to the cement until the batter will support a needle of diameter equal to one-twelfth of an inch and weighted with a quarter of a pound. The final set is the time elapsing from the addition of the water until the batter will support a needle of one twenty-fourth inch diameter weighted with one pound. As the time of setting will depend on the amount of water used, that quantity which with trowelling will first cause a gloss to appear on the surface of the batter is recommended. In other words, a minimum of water is to be employed.

The specifications, for standard Portland cement, of the Canadian Society of Civil Engineers, and of the American Society for Testing Materials, are appended:

The Canadian Standard

The standard specifications of the Canadian Society of Civil Engineers are as follows:

The whole of the cement is to be well-burned pure Portland cement, of the best quality, free from free-lime, slag, dust, or other foreign material.

(1) *Fineness*: The cement shall be ground so fine that residue on a sieve of 10,000 meshes to the square inch shall not exceed 10 per cent. of the whole by weight, and the whole of the cement shall pass a sieve of 2,500 meshes to the square inch.

(2) *Specific Gravity*: The specific gravity of the cement shall be at least 3.09, and shall not exceed 3.25 for fresh cement; the term "fresh" being understood to apply to such cements as are not more than two months old.

(3) *Tests*: The cement shall be subjected to the following tests:

(a) Blowing Test: Mortar tests of neat cement, thoroughly worked, shall be trowelled upon carefully cleaned 5-inch by 2½-inch ground glass plates. The pats shall be about ½-inch thick in the centre, and worked off to sharp edges at the four sides. They shall be covered with a damp cloth and allowed to remain in the air until set, after which they shall be placed in vapor in a tank, in which the water is heated to a temperature of 130° F. After remaining in the vapor six hours, including the time of setting in air, they shall be immersed in the hot water and allowed to remain there for eighteen hours. After removal from the water the samples shall not be curled up, shall not have fine hair cracks, nor large expansion cracks, nor shall they be distorted. If separated from the glass, the samples shall break with a sharp, crisp ring.

(b) Tensile Test, Neat Cement: Briquettes made of neat cement, mixed with about 20 per cent. of water by weight, after remaining one day in air, in a moist atmosphere, shall be immersed in water, and shall be capable of sustaining a tensile stress of 250 lb. per square inch, after submersion for two days; 400 lb. per square inch after submersion for six days; 500 lb. per square inch after submersion for 27 days. The tensile test shall be considered as the average of the strength of five briquetttes, and any cement showing a decrease in tensile strength on or before the twenty-eighth day shall be rejected.

Sand and Cement: The sand for standard tests shall be clean quartz, crushed so that the whole shall pass through a sieve of 400 meshes per square inch, but shall be retained on a sieve of 900 meshes per square inch. The sand and cement shall be thoroughly mixed dry, and then about 10 per cent. of their weight of water shall be

added, when the briquettes are to be formed in suitable moulds. After remaining in a damp chamber for 24 hours, the briquettes shall be immersed in water, and briquettes made in the proportion of one of cement to three of sand by weight, shall bear a tensile stress of 125 lb. per square inch after submersion for six days, and 200 lb. per square inch after submersion for 28 days. Sand and cement briquettes shall not show a decrease in tensile strength at the end of 28 days or subsequently.

(4) The manufacturer shall, if required, supply chemical analyses of the cement.

(5) *Packing*: The cement shall be packed either in stout air and water-tight casks, carefully lined with strong brown paper, or in strong air and water-tights bags.

(6) The manufacturer shall give a certificate with each shipment of cement, stating (1) the date of manufacture; (2) the tests and analyses which have been obtained for the cement in question at the manufacturer's laboratory; (3) that the cement does not contain any adulteration.

The American Standard

The standard of the American Society for Testing Materials is as follows:

Definition. The term Portland cement is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than three per cent. has been made subsequent to calcination.

Specific Gravity. The specific gravity of the cement, thoroughly dried at 100° C (boiling point) shall not be less than 3.10.

Fineness. It shall have by weight a residue of not more than eight per cent. on a No. 100 sieve, and not more than twenty-five per cent. on a No. 200 sieve.

Time of Setting. It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour nor more than ten hours.

Tensile Strength. The minimum requirements for tensile strength for briquettes one inch square in section shall be within the following limits, and shall show no retrogression in strength within the periods stated.

Neat Cement

24 hours in moist air	150 to 200 lb.
24 hours in moist air and 6 days in water	450 to 550 lb.
24 hours in moist air and 27 days in water	550 to 650 lb.

One part cement to three parts sand:

24 hours in moist air and 6 days in water	150 to 200 lb.
24 hours in moist air and 27 days in water	200 to 300 lb.

Constancy of Volume. Pats of neat cement about three inches in diameter one-half inch thick at the centre and tapering to a thin edge shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature and observed at intervals for at least twenty-eight days.

(b) Another pat is kept in water maintained as near seventy degrees F. as practicable, and observed at intervals for at least twenty-eight days.

(c) A third pat is exposed in any convenient way in an atmosphere of steam above boiling water, in a loosely closed vessel for five hours.

These pats to satisfactorily pass the requirements shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

Sulphuric Acid and Magnesia. The cement shall not contain more than 1.75 per cent. of anhydrous sulphuric acid (SO_3) nor more than 4 per cent. of magnesia (MgO).

USES OF CEMENT

In general, cement for construction purposes is employed in two ways, namely, in mortar and in concrete, either plain or reinforced with metal. It is almost never used commercially neat, that is, without sand. Sometimes, however, for grouting masonry, the neat paste is employed, experience having proved that there are almost uncontrollable tendencies on the part of the sand in a grouting mortar to separate from the cement, to choke passages, and to cause voids to occur.

Experiments in the use of cement as a protection to bridge steel in structures have proved its usefulness. Structural steel exposed to the gases of passing locomotives for example, shows a rapid and harmful corroding, which a paste of cement, red lead and japan has proved very efficacious in arresting. It is the custom to apply this paste in a thickness of one-quarter of an inch. Further experiments will no doubt confirm the finding of those who have tried this preventive to corrosion. These uses and some others, for example the utilization of cement as a pigment in paint, must be regarded as special.

For Making Mortar

The use of mortar is exceedingly ancient. Lime mortar has been employed in the masonry of southern Europe, particularly in Italy, for twenty centuries, but in its durability, its strength and the variety of uses to which it may be put, it is quite inferior to its more modern rival, Portland cement mortar. It is generally believed that the ultimate hardening of lime mortar is due to the absorption from the air of carbonic acid gas, which in combination with the lime forms a limestone. Hence it follows that lime mortar which has been thoroughly exposed to the atmosphere for a sufficiently long time will approach more or less in chemical composition and hardness the common limestone with which all are familiar.

Lime versus Cement

Analyses made of lime mortars taken from the structures of antiquity demonstrate, however, the following: the mortar is never completely changed to the carbonate of lime except at the surface, and where mortars have been excluded from all air, no change even after the lapse of centuries has taken place. The great time necessary to accomplish the complete hardening of lime mortars is a serious objection to their use in many cases. The structure in which they have been used may, due to settling of foundations or to the weight of material above it, deform seriously before it has developed a sufficient hardness to ensure safety. Again, the evolution of the modern tall building has rendered necessary a radical change. Lime mortar is many times weaker in compressive strength than is a mortar of similar mixture containing Portland cement, the latter of which will in time equal clay brick in compressive strength. Lime mortar of a mixture three to one at the age of a year will average a tensile strength of 50 lb. per square inch, or a compressive strength approaching 500 lb. per square inch. Cement mortar, three to one of the same age, will give a tensile strength of 400 lb. per square inch, and a compressive strength approaching 4,000 lb. or about the strength of a good clay brick, as said above. In other words, the strength of cement mortar is approximately eight times that of lime mortar of the same mixture and age.

Results of tests made under the direction of Prof. C. H. C. Wright, of the School of Practical Science, Toronto, on brick piers using lime mortar of certain proportions in one series, and cement mortar in another are given below. The bricks, age and

other conditions being as nearly identical as possible, we see that the latter are capable of resisting from two to four times as great a load per unit of area.

Description of Pier.	Crushing strength.			
	Lime mortar, 2 to 1.		Cement mortar, 3 to 1.	
	lb. per sq. in.	tons. per sq. ft.	lb. per sq. in.	tons. per sq. ft.
Humber Brick, 2nd class, 8 courses	293	21	1,131	81.4
Carleton Clinker, 8 courses	609	43.8	2,408	173.4
Yorkville Brick No. 1, white	509	36.6	1,062	76.5
Yorkville Brick, No. 2, 8 courses	392	28.2	1,018	73.3

The inconsistency of laying good clay brick in lime mortar where the structure is to be subjected to heavy loading, lies in the manifest inequality in point of strength of the bricks and their jointing. Further, the fact that lime mortar cannot be laid in water, and will not harden under water, renders it useless for all kinds of hydraulic and submarine work. So, too, its porosity, especially in damp and frosty situations puts another limitation on its use as a material of construction.

What Mortar Is

A mortar is made by thoroughly mixing sand, cement and water in varying proportions. Of sand there are many kinds differing in composition, angularly, size of grains, etc. Experience seems to prove that a limestone or calcareous sand is generally to be preferred to a silica or quartz sand, there being usually a better bond between the cement and the grains in the case of the former.

For submerged or impervious work solid mortar is necessary, and for almost all uses it is desirable. A solid mortar is obtained by having a quantity of cement equal to or slightly in excess of the voids in the said, there being usually a better bond between film of cement completely or almost completely surrounding it. It will be agreed that a sand whose grains are of uniform size will have a greater percentage of voids than will a sand with grains of varying size. Hence it follows that the latter will require a less quantity of cement to produce a solid or impervious mortar. The eight thousand grains contained in one cubic inch of sand, each grain being one-twentieth of an inch in diameter, present an external area of one hundred and twenty square inches against one hundred and seventy-six square inches where the grains are one-thirtieth of an inch in diameter. From this it is seen that the "covering power" of cement will be greater in a coarse sand; or what is probably the same thing, for equal strengths, more cement will be needed with a fine variety, solidity not being an essential. Again, for the same proportions of ingredients in mortar, greater strength will be obtained with a coarse sand than with a fine one.

Sand for Mortar

The question of voids in a sand where a solid and impervious mortar is desired is important. The percentage of voids in any case may be easily obtained by adding water to the sand in a water tight vessel until it flushes even with the surface of the sand. The increase in weight due to the added water, converted into units of volume and expressed as a percentage of the volume of the sand, is the process in brief.

Voids in sands vary from tweny-five to fifty per cent., or from a quarter to a half of the wetted volume which is on an average, twenty per cent. less than the volume when dry. It should be remembered, too, that a shrinkage in the cement on the

addition of water may be put at ten per cent. Suppose we desire a solid mortar from a sand with thirty-five per cent. of voids. It is evident that a three to one mixture will give this with a small margin, since the voids would be $^{35}/_{100}$ of $(3 \times {}^{80}/_{100}) = .84$ and the cement available to fill these voids would be $^{90}/_{100}$ of $1 = .90$.

The essentials of a good sand are usually stated in specifications to be cleanness, coarseness and sharpness. The cleanness is understood to be freedom from loam, clay or organic matter, and the sharpness as synonymous with angularity. A number of tests for the purpose of discovering the effect of clay in a three to one mortar were made last fall in the cement laboratory of the School of Practical Science. The percentage of clay varied from two to six per cent, the other elements being constant. It will be seen from the following summary that in all cases the effect of the clay was to increase the tensile strength. It would appear then as if small percentages of this material are not objectionable in a cement mortar.

Age, 28 days.	
Per cent. of clay.	Average tensile strength.
0	209
2	248
4	223
6	233

The effect of adding sand to a cement is to weaken it, no mortar being as strong as a neat cement. The following table is given as representing the relative strengths in the average case.

Mixture.		Relative Strength.
Cement.	Sand.	
1	0	1
1	1	⅔
1	2	½
1	3	⅓
1	4	¼

The Use of Lime Paste

The practice of adding lime paste to cement mortar for plastering and other purposes is quite common, the objects sought being cheapness, strength, imperviousness and a desire to attain a smoothness in working not possible with cement alone. Investigation seems to prove that an addition of lime paste not exceeding twenty per cent. of the mortar will not reduce the strength, and in some cases appears to increase it. While slightly reducing the cost, it gives the mortar a "body" very much desired by the workmen. Beyond the limit given, it is perhaps not wise to go if strength is a factor sought.

The Owen Sound Portland Cement Company, in their brochure on the uses of cement suggest the following: "If it is desired to make water-tight mortar for cisterns and reservoirs, and where absolutely water-tight work is required, the following proportions are recommended:

Portland cement.	Sand.	Lime paste.
1 part	2 parts	½ part
1 part	3 parts	1 part

For brick work, Samson Portland cement, mixed with nine parts of sand and one part of lime paste is recommended, although the cheaper proportion of one part of cement, eight of sand, and one and a half of lime paste will give excellent results."

For Impervious Mortar

With the object of determining the causes and remedies for permeability of cement by water, a series of experiments was conductd in 1901 and 1902 in the State University, Columbus, Ohio. In view of the fact that cement is being employed extensively where it is subjected to hydraulic pressure, as in sewers, watermains and reservoirs, a summary of the finding may be interesting. It is as follows:

"The permeability cannot be materially reduced by the application of soap and alum solutions or by finely powdered loam used in the sand, but it can be reduced (1) by the application of one to five coats of cement grout, the reduction amounting to from seventy to ninety-eight per cent. of the initial leakage; (2) by a coating of neat cement mortar one quarter of an inch thick; (3) by the mortar surface standing under a head of water containing suspended matter."

The mixing of the sand and cement should be thoroughly done dry until the color is uniform. Then the water should be added and the whole mass turned over until every part is thoroughly wetted. It is as possible to weaken a mortar by too much water as it is by too little. The correct quantity depends on the size and dryness of the sand, and to some extent on the kind and age of the cement.

The following table is taken from a circular issued by the Buckeye Portland Cement Company of Harper, Ohio, and gives the amount of cement, sand and lime paste needed to lay one thousand bricks.

Mortar in all cases 6 : 1 : 1.

Joint.	Proportion of mortar to brick.	Bus. of sand.	Bbls. of cement.	Bus. of lime.
⅛ in.	1 to 9	3.8	.21	.64
¼ "	1 " 4	9.6	.53	1.6
⅜ "	3 " 10	12.5	.70	2.1
½ "	1 " 3	15.2	.83	2.5

For Making Concrete

The second use of cement is in concrete. Concrete consists of a "matrix" and an "aggregate." The matrix is defined as the cement and the sand plus the water. The aggregate may be broken stone, shingle, cinders, slag, etc. The remarks *re* solid and impervious mortar will apply also to a solid and impervious concrete. For a solid concrete the voids in the aggregate should be filled with the mortar, which in turn should contain sufficient cement to fill all cavities in the sand. It should, however, be stated that very good and serviceable concrete may be obtained where no attempt is made to procure a solid mass. The quantity of voids in an aggregate depends on the uniformity or lack of uniformity in size and shape of the individual parts. To reduce this quantity, it is evident that there should not be uniformity of size. The voids in an aggregate will vary from twenty-five to fifty per cent.

Suppose it is desired to produce a solid concrete knowing the voids to be as follows: sand, 35 per cent., aggregate, 40 per cent. We know from the previous discussion that a three to one mixture will give a solid mortar, remembering that sand and cement shrink twenty and ten per cent. respectively on the addition of water. The volume of this mortar will probably be about equal to that of the wetted sand, or $^{80}/_{100}$ of $3 = 2.4$ volumes. These 2.4 volumes would by a simple calculation be the voids in six volumes of aggregate of the character assumed. This means then, that a 1:3:6 mixture will secure the solidity desired.

Gravel and water-worn shingle are often employed as an aggregate in rough work. Their value will much depend on their freedom from loamy and other earthy matters, but their lack of angularity is an objection. This affects the strength of the concrete, the bond between the cement and the aggregate being more easily broken where smooth pebbles are used for the latter. This bond is doubtless strongest where

the aggregate is crushed limestone. Cinders and slag have the advantage of being light though lacking the strength of the stone. The weight of limestone concrete is about 150 pounds per cubic foot, while that of cinder concrete is about 100 pounds. For flooring purposes and where resistance to fire and economy are considerations, this latter commends itself.

The process of mixing should be thorough. The sand and cement should be mixed dry, after which the stone should be added, and all thoroughly mixed again. The addition of the water and a turning over a sufficient number of times to wet the whole mass complete the process of preparation. Thorough ramming until water flushes to the surface will improve the strength of concrete though care should be taken not to prolong the ramming past the point where initial set begins. For the same reason a batch only of such size as can be put in place before setting has begun should be mixed at a time. Where a large quantity of concrete is required, it is more economical to employ some good type of mixing machine. Such a machine should be so designed that the complete dry mixing of the sand and cement can be done before the aggregate and water are added. Machines should be so constructed that the mixing may be continued until a satisfactory and complete incorporation is obtained. In continuous mixers, this is apt not to be provided for.

The Uses of Concrete

Concrete as a material for the construction of all kinds of foundations has to a great extent replaced stone masonry of late years. Its cheapness, and the fact that skilled labor is not required in putting it in place, have undoubtedly been the chief encouragements in its use. For bridge abutments, piers and arches, building foundations, canal locks, walls of dwellings and warehouses, floors, dams and breakwaters, street pavements and sidewalks, etc., concrete has "come to stay."

The character of the mixture used in any case will depend on the strength required. The Hanover Portland Cement Company recommend the following: "According to the importance of the work, the proportions for concrete may be as follows: one part of good Portland cement, three to eight parts of sand, and from seven to fourteen parts of gravel or crushed stone." Cases are on record where a concrete of surprising strength was obtained from a 1:30 mixture, but such lean concretes are not recommended. Indeed, it is no doubt a fact that good brands of cement are sometimes blamed for failures in concrete construction where the leanness of the mixture was wholly at fault.

In work of any considerable magnitude, provision for expansion and contraction due to temperature changes should be made. This provision usually takes the form of "expansion joints" or bulkheads which are merely vertical seams dividing the work into blocks. Partitions of paper or of sand are sometimes employed for this purpose. They should be placed at intervals of thirty to fifty feet.

Concrete and Steel

Until recently, concrete has simply replaced stone in building operations. It has the same mechanical properties, and shares the same defects. Under certain conditions though, it has proved superior to its ancient rival. Within the last generation, new possibilities have opened to concrete through the careful and intelligent addition of steel, the combination bringing into use the good qualities of both materials. "Re-inforced concrete" is a term which of late years has been used to designate this combination. It is also known as "concrete-steel" and as "armoured concrete." It is a well-known fact that the strength of concrete, unlike that of steel or timber, is many times greater in compression than it is in tension. It was probably a recognition of this peculiarity that led to the practice of putting steel in concrete to assist that element of strength which the concrete lacks. In Europe, especially, where its use

has become general, it has been endorsed by the most eminent engineers. In America it is finding new uses monthly, and the increasing cost of wood will tend to render it more popular in the future than it is even in the present day.

Regarding concrete steel, The Engineering Magazine in a recent issue had this to say editorially:

"Among the many advantages of concrete-steel may be mentioned cheapness as compared with other types of massive construction, lightness, economy of space on account of thinness of walls, capacity for carrying heavy loads, ready adaptability to any desired form, speed of construction, fire-proof qualities and safety on a very poor foundation material, since the structure hangs together as a whole and when overloaded does not collapse suddenly, but tends to deform gradually. There are two important respects in which steel construction gains by the addition of concrete. These are protection against rust, and protection against injury by fire."

Re-inforced concrete is the only form of construction that is really permanent. It is not susceptible to atmospheric influences like stone masonry, and when properly built it will not crack like plain concrete. Such cracks lead to ultimate deterioration due to the action of water and frost.

So far as records inform us, the first man to make intelligent application of steel in concrete was W. E. Ward, of Port Chester, N. Y., who erected in 1875 a building in which "not only all the external and internal walls, cornices and towers, were constructed of béton, but all the beams and roofs were exclusively made of the same material re-inforced with light iron beams and rods." Probably the first approximately correct formulae giving the strength of steel and concrete in combination were derived by Julius Mandel in Germany, and by the late Professor J. B. Johnson in America, about the same time.

The indefatigable investigator, Considère of Paris, during the eighties made a series of very valuable contributions to the literature of the subject. The conclusions at which he arrived may be briefly summarized as follows:

1. In armed concrete beams, the concrete on the tension side will submit without rupture to a proportionate distortion of from ten to twenty times that at which it would fail in an unarmed direct tension test. It will also have during the additional period of distortion a strength nearly equal to its maximum strength in direct tension.

2. Several interior stresses are introduced in armed concrete constructions, where rich concrete mixtures are used owing to the shrinkage of the latter during the first eighteen months if exposed to the air, or a corresponding swelling during this period if in submarine work.

3. These interior stresses are to a considerable extent relieved by the slipping of the bars or rods in the concrete, as to which action tests leave no room for doubt. The stress is also relieved in time if cracks are not previously developed by what has been called the tendency of the concrete to eventually yield somewhat to a soliciting force.

The slipping of rods in concrete in which they are imbedded undoubtedly occurs through the weakening of the adhesion between the metal and its surrounding medium, which is very great at first. This weakening is accelerated by vibration and shock to which more or less, all structures are subjected.

Re-inforced Concrete Beams

Last year, a series of tests on re-inforced concrete beams was carried on at the Experiment Station at the University of Illinois. A summary of the conclusions reached may be of interest.

"In beams with the metal re-inforcement small enough in amount not to develop the full compressive strength of the concrete, the maximum load is reached or nearly reached when the metal is stretched to its yield point, and in calculating the resisting moment, the tensional value of the concrete is here negligible and the load at the yield point of the metal may well be considered the full strength of the beam.

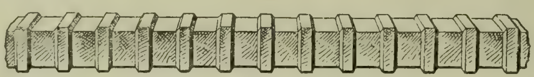
So far as strength of the beam is concerned, the load when the steel is stressed to its elastic limit seems the prcper basis for the factor of safety and working load. So far as strength of the beam is concerned, steel having a high elastic limit is advantageous, it being assumed that there is sufficient provision against the slipping of the rods and shearing failures.

"The determination of the limit of re-inforcement which may properly be used with different mixtures and grades of concrete may best be decided by experiments on beams made to determine this. For the 1 : 3 : 6 concrete used, re-inforcement as high as $1\frac{1}{2}$ per cent. for the steel of 33,000 lb. pr square inch elastic limit, and 1 per cent. for steel of 55,000 lb. per square inch elastic limit may be used without developing the full compressive strength of the concrete.

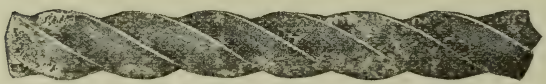
"There was no marked difference in results found for the different forms of re-inforcing bars used."

Systems of Re-inforcement

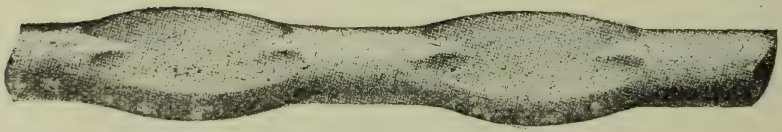
Re-inforced concrete has found uses whose name is legion, and has led to the evolution of numerous so-called "systems" of re-inforcement. It is regularly employed in the construction of beams and girders, floors and walls, columns, bridge arches, piles, reservoirs, chimneys, lighthouses, sewers, dams, railway ties, fence posts and a number of other purposes too numerous to mention in detail. Most of the so-called systems have features peculiar to themselves, and many of these are undoubtedly meritorious. There is always this, however, that with careless workmanship or lack of intelligent and careful supervision, the best features of any method may be completely nullified. A good system combined with care and intelligence in the application of correct methods will give good results.



Johnson Corrugated Bar.



Ransome Twisted Bar.



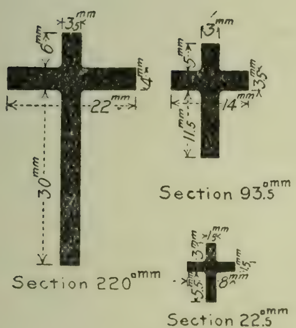
Thacher Rolled Bar. ("Reinforced Concrete" p. 335.)

Thaddeus Hyatt of England investigated the subject of steel and concrete in combination as early as 1876, and the system that still bears his name consists of a series of perforated bars, through the perforations of which pass wires or rods. The whole forms a network of rectangular meshes. It was adapted to such purposes as floor construction.

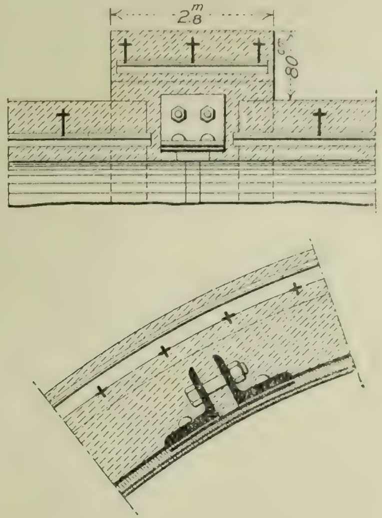
Monier of France attempted the strengthening of concrete by steel about the same time. The Monier system, like the Hyatt, is a network of two series of parallel steel or iron rods which intersect at right angles. Each junction is secured by a wire. The rods are distinguished as "carrying" and as "distributing," according to the purpose they serve. The mesh is from two to four inches to a side.

Ransome employed cold-twisted square rods imbedded near the lower surface of his beams and floor slabs. The cold twisting raises the tensile strength and elastic limit of the metal, and the value of this is pretty generally recognized.

The Bonna system is applied chiefly to the construction of pipes. The steel sections are cross-shaped, and encircle the pipe or sewer spirally or in rings. There are other similarly shaped rods intersecting these and lying parallel to the axis of the pipe line. Concrete completely conceals the steel.



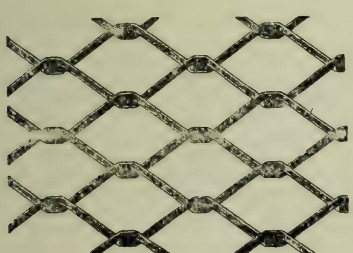
Bonna re-inforcing Bars for cast-pipe sewer.



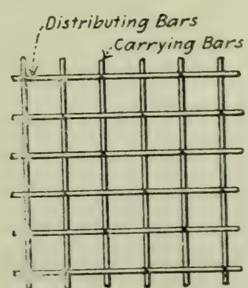
Detail of coupling for cast-pipe sewer. Bonna System.

The Roebling system consists of a woven net of wire stiffened at intervals with parallel steel rods. Webs of this net are sprung in between floor beams or girders, and on this the concrete is deposited. For ceilings, webs of similar netting may be suspended from the lower flanges of the floor beams, the plaster being applied thereto.

Expanded metal has acquired a good and growing patronage. It is a netting of diamond-shaped meshes, which by powerful shearing machines is cut direct from the web of sheet metal. For floor construction especially it has been very favorably received, Temporary wooden forms to support the floor have to be put in place. On



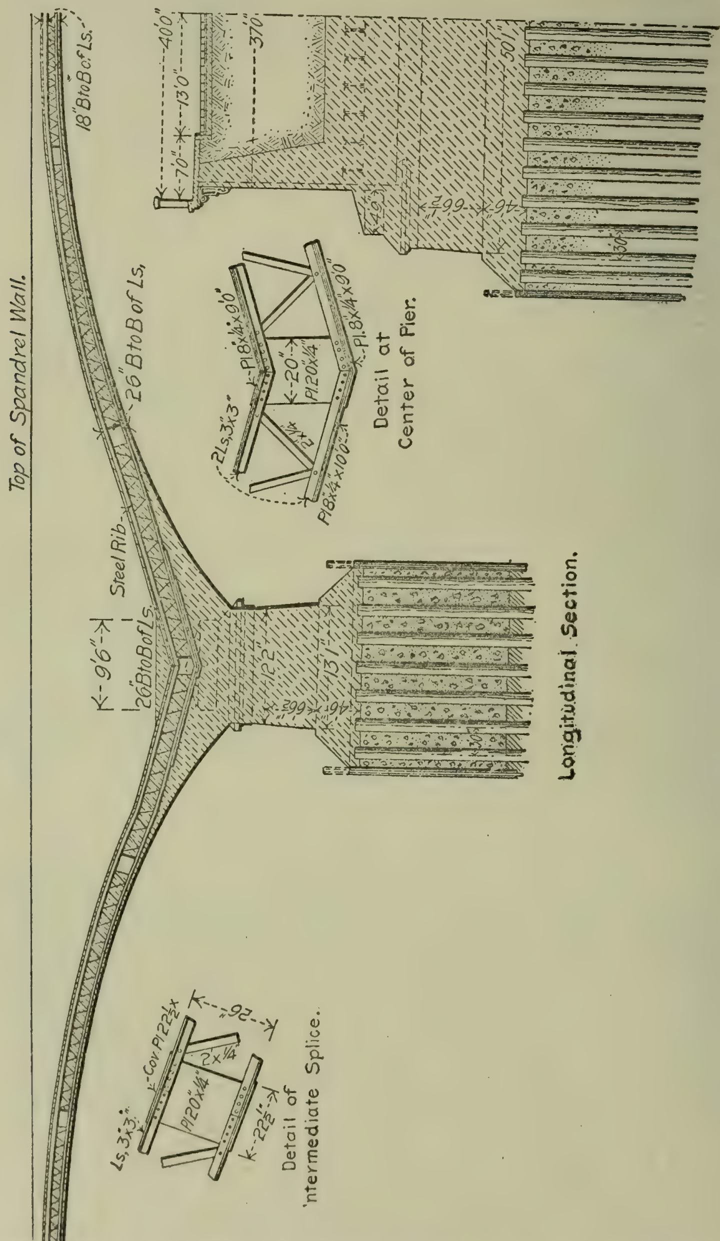
Expanded Metal.



Monier Netting.

these expanded metal is first laid, and then the concrete spread. To imbed the steel perfectly, the web of metal is lifted slightly with hooks, allowing the concrete to pass below and around the steel. The whole is thoroughly rammed, and after a suitable time, the forms are removed. Expanded metal is also recommended for strengthening concrete water towers, sewers, and for thin partitions in dwellings and buildings generally. The studding in the latter case is usually a series of upright inch or inch-and-a-quarter channels.

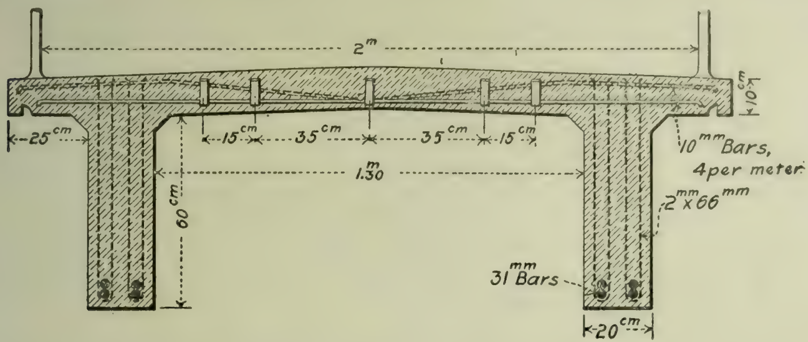
The Melan system is adapted principally for arch construction. Arched I beams or built up plate girders are constructed of a span sufficient to reach from abutment to abutment. These are spaced about two feet centres, and the space between and around them is filled with concrete.



Pier and Arch Construction of Melan Arches at Topeka, Kan. ("Re-inforced Concrete" p. 217.)

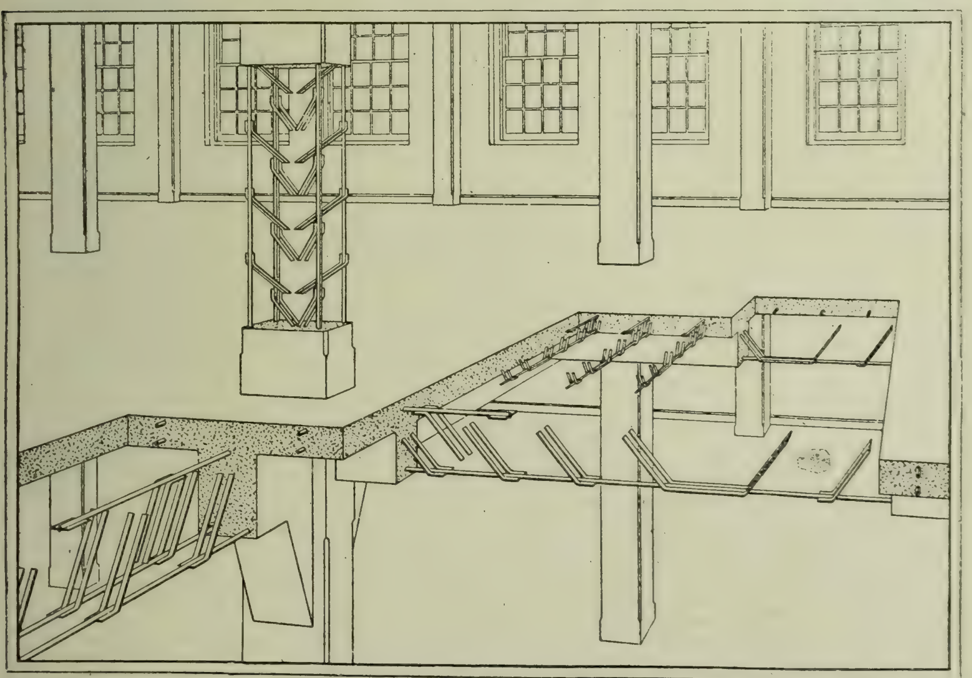
The feature of the Hennebique system is the use of the metal stirrup to resist the tendency to failure by oblique shear at the ends of the beams. These beams are reinforced by imbedded rods placed near the lower face, and at times by others near the upper face, to give rigidity and assist in resisting compressive stresses. The stirrups are of length slightly less than the height of the beams, and carry the

tension rods in their bends, the arch of the stirrup being downward. They are spaced more closely toward the ends, and are absent altogether at the middle section of the beam. Usually some of the tension rods are bent upward at the two ends, the object being to assist the U-shaped members in preventing end failure. The system lends itself admirably to the construction of columns. It has been very extensively used on the continent.



Hennebique System. Cross-section of Girder Bridge.
Note.—All dimensions are in the Metric System.

The Kahn system makes use of a "trussed bar" of steel with "fins" inclined outwards and upwards at 45° at both ends. Its merit seems to be that where tension

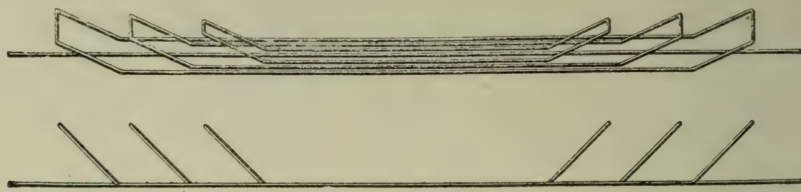


Perspective view of general adaptation of the Kahn System   Trussed Concrete Steel Co.

alone is required, there is a maximum of metal available, and that to resist end-shear, oblique members more or less at right angles to the line of probable failure are provided. It is specially adapted for floors, columns and beams.

The Cummings system is analogous to that of Kahn. Here, however, round rods in nests of parallelograms are used, the ends of each being bent upwards, as are the

fins on the Kahn bar. The extra number of pieces required renders the placing of the metal somewhat more complicated than where a single bar is employed.



Cummings Bars.

The De Marr system makes use of flat steel bars having quarter turns alternately right and left every two inches or thereabouts, according to size. These bars connect from top to top of I beams, and in this way support the floor. It is frequently employed with a specially constructed tile or concrete floor block, which is used to build in between girder and girder.

In an article written for the Journal of the Royal Institute of British Architects, Mr. Frank Cawes gives the following rules for the construction of floors. No doubt it represents good English practice.

1. Obtain good cement.
2. Use good broken brick aggregate and not sand; body concrete to be of one part cement and four parts brick and the surface to be one part cement and three parts crushed granite.
3. Use as a precaution "sheep-wire netting" as a base, and steel bars of 1½ pounds per foot in weight spaced three feet apart.
4. Consider a slab 10 feet square by 4 inches thick capable of bearing 900 pounds per foot including its own weight, and reckon for every slab, more or less than 900 pounds per foot directly in proportion to the square of the thickness and inversely as the cube of the span. When the span is rectangular, the minimum span is taken.
5. Avoid casting slabs in frosty weather.
6. Cast large areas at once; have no partially cast slab over night.
7. Insist on strong centering. Leave it up at least five weeks.

SPECIFICATIONS FOR CONCRETE

The following specifications for Portland cement concrete are recommended by a committee of the American Railway Engineering and Maintenance of Way Association:

Cement: Cement shall be Portland, either American or foreign, which will meet the requirements of the standard specifications.

Sand: Sand shall be clean, sharp and coarse, but preferably of grains varying in size. It shall be free from clay, loam, sticks and other impurities.

Stone: Stone shall be sound, hard and durable, crushed to sizes not exceeding two inches in any direction, and freed from dust by screening.

Gravel: Gravel shall be composed of clean pebbles of hard and durable stone, of sizes not exceeding two inches in diameter, free from clay and other impurities except sand. When containing sand in any considerable quantity, the amount per unit of volume of gravel shall be determined accurately to admit of the proper proportion of sand being maintained in the concrete mixture.

Water: Water shall be clean and reasonably clear, free from sulphuric acid or strong alkalies.

Mixing by Hand: (1) Tight platforms shall be provided of sufficient size to accommodate men and materials for the progressive and rapid mixing of at least two batches of concrete at the same time. Batches shall not exceed one cubic yard each, and smaller batches are preferable, based upon a multiple of the number of sacks to the barrel.

(2) The sand shall be spread evenly upon the platform, then the cement upon the sand, and all mixed thoroughly until of a uniform color. The water necessary to make a thin mortar shall be added, and the whole spread again. The gravel, if used, shall then be added, and finally the broken stone, both of which, if dry, shall be first thoroughly wetted down. The mass shall then be turned with shovels or hoes until

thoroughly mixed and all gravel and stone are covered with mortar. This will probably require four turnings.

(3) Another approved method which may be permitted at the option of the engineer in charge is to spread the sand, then the cement, then the gravel or broken stone. Add water and mix thoroughly as above.

Mixing by Machine: A machine mixer shall be used whenever the volume of work will justify the expense of installing the plant. The necessary requirements for the machine will be that a precise and regular proportioning of materials can be controlled, and the product delivered shall be of the required consistency and thoroughly mixed.

Consistency: The concrete shall be of such consistency that when dumped in place it will not require much tamping. It shall be spaded down and tamped sufficiently to level off, and will then quake freely like jelly.

Course: (1) Each course shall be left somewhat rough to insure bonding with the next course above, and if it be readily set, shall be thoroughly cleaned and dampened before the next course is placed upon it. The plane of courses shall be as nearly as possible at right angles to the line of pressure.

(2) An uncompleted course shall be left with a vertical joint where the work is stopped.

(3) The work shall be carried up in sections of convenient length and completed without intermission.

Expansion Joints: (1) In exposed work expansion joints shall be provided at intervals of thirty to fifty feet. A temporary vertical form or partition of plank shall be set up and the section behind completed as though it were the end of the structure. The partition will be removed when the next section is begun and the new concrete placed against the old without mortar flushing. Locks shall be provided if directed or called for by the plans.

(2) In re-inforced or steel concrete the length of these sections may be materially increased at the option of the engineer.

Time: Concrete shall be placed immediately after mixing, and any having an initial set shall be rejected.

Facing: About one inch of mortar of the same proportions as used in the concrete may be placed next to the forms immediately in advance of the concrete, or a shovel facing made, at the option of the engineer in charge.

Forms: (1) Forms shall be substantial and unyielding, properly braced or tied together by means of wire or rods.

(2) The material used shall be dressed lumber secured to the studding or uprights in horizontal lines.

(3) Planking once used in forms shall be cleaned before being again used.

(4) The forms must not be removed within forty-eight hours after all the concrete in that section has been placed. In freezing weather they must remain until the concrete has had a sufficient time to become thoroughly set.

(5) In dry but not freezing weather, the forms shall be drenched with water before the concrete is placed against them.

(6) For backings, undressed lumber may be used for forms.

Finishing: (1) After the forms are removed any small cavities or openings in the concrete shall be neatly filled with mortar if necessary. Any ridges due to cracks or joints in the lumber shall be rubbed down. The entire face shall then be washed with a thin grout of the consistency of whitewash, mixed in the proportion of one part cement to two ports of sand. The wash shall be applied with a brush.

(2) The tops of bridge seats, pedestals, copings, wing walls, etc., when not finished with natural stone coping, shall be finished with a smooth surface composed of one part cement to two parts of sand. The wash shall be applied with a brush.
1 to 1½ inches thick. This must be put in place with the last course of concrete.

(3) In arch tops, a thin coat of mortar or grout shall be applied over the top to thoroughly seal the pores.

TESTS OF ONTARIO CEMENT

Following are the results of some experiments made with Ontario cements. It may be explained that samples of the various brands experimented with were either procured by the writer personally at the works, or were taken by him from original packages offered for sale by dealers in the open market, the packages bearing the maker's name and brand. Due care was exercised in every instance to get a fair sample of ordinary product. The experiments were made by the writer in the laboratory of the School of Practical Science, Toronto.

Sieve Test

Brand.	Residue on 50-mesh sieve.	Residue on 100-mesh seive.
	Per cent.	Per cent.
Portland:		
Monarch	0.1	5.7
Sun	0.0	1.9
National	0.1	1.7
Star	trace.	3.9
Samson	0.0	3.5
Imperial	trace.	5.4
Hercules	trace.	5.2
Saugeen	0.1	2.9
Giant	0.4	9.0
Natural Rock:		
Schwendiman's	2.3	12.9
Battle's	7.2	19.5
Ontario Lime Co's	6.1	15.7
Usher's	7.6	18.9

Hot Test

Pats were 6 hours in warm moist air, and 18 hours in water at 120° F.

BRAND.	REMARKS.
Portland:—	
Monarch	Satisfactory.
Sun	Satisfactory.
National	Satisfactory.
Star	Satisfactory.
Samson	Satisfactory.
Imperial	Pat separated from glass.
Hercules	Satisfactory.
Saugeen	Satisfactory.
Giant	Satisfactory.
atural Rock:—	
Schwendiman's	Satisfactory.
Battle's	Satisfactory.
Ont. Lime Co.'s	Disintegrated in hot bath.
Usher's	Pat slightly curled up at edges.

Tensile Strength

Brand.	3 days.	7 days.	28 days.	Remarks.
	lb.	lb.	lb.	
Portland:				
Monarch	295	423	363	
Sun	343	483	798	
National	450	843	753	
Star	385	595	525	
Samson	320	458	608	
Imperial	465	720	903	
Hercules	338	648	910	
Saugeen	318	423	488	
Giant	400	593	618	
Natural Rock:				
Schwendiman's	51	54	115	
Battle's	80	95	138	
Usher's	80	100	103	

Tensile Strength—Mortar Test

Brand.	7 Days.	28 Days.	Remarks.
Portland, 3 to 1:			
Monarch	128	293	
Sun	168	308	
National	250	285	
Star	173	293	
Samson	128	210	
Imperial	163	260	
Hercules	208	270	
Saugeen	148	225	
Giant	150	250	
Natural rock, 1 to 1:			
Schwendiman's	48	130	
Battle's	73	133	
Usher's	28	125	

Samples of marl, limestone and clay, believed to be representative of the raw materials used or proposed to be used by the various companies mentioned in this report, were collected by the writer when visiting the plants. These were sent for analysis to Mr. A. G. Burrows, B.A., Sc., Provincial Assayer, Belleville, whose reports thereon are appended.

Analyses of Marls and Limestones

Name.	SiO_2. Per cent.	Fe_2O_3 Per cent.	Al_2O_3 Per cent.	$CaCO_3$ Per cent.	$MgCO_3$ Per cent.	SO_3 Per cent.	Loss. Per cent.
PORTLAND:							
Hanover Portland Cement Co.	.58	.57	....	92.00	4.74	.52	1.66
Grey & Bruce Portland Cement Co.	2.00	.50	.84	84.91	2.89	1.21	6.60
Colonial Portland Cement Co.	.59	.64	....	87.39	2.96	.79	8.23
Lakefield Portland Cement Co.	.52	.16	....	93.43	.60	.51	4.07
Sun Portland Cement Co.	1.38	1.30	....	87.51	2.97	1.06	4.83
Imperial Portland Cement Co.	1.66	.63	.27	87.87	4.12	.72	5.69
Belleville Portland Cement Co.	4.12	.50	.93	92.29	1.42	.40	....
Ontario Portland Cement Co.	.30	.47	....	91.69	2.24	.41	2.22
International Portland Cement Co.	1.12	.38	.22	97.61	.51	.44	.20
Canadian Portland Cement Co.	.22	.18	....	94.61	.98	.64	3.19
National Portland Cement Co.	.74	....	.42	89.37	3.33	.60	5.65
Owen Sound Portland Cement Co	1.06	.82	.20	93.26	2.20	.51	2.41
Superior Portland Cement Co.	.26	....	.36	92.08	3.27	.55	3.67
NATURAL ROCK:							
Toronto Lime Co.	7.04	1.51	2.34	48.27	40.36	.43	....
Isaac Usher	17.29	2.36	1.43	49.39	29.46	1.64	....
F. Schwendiman	10.08	1.77	3.31	46.18	37.77	1.40	....

Analyses of Clays

Name.	SiO_2 Per cent.	Fe_2O_3 Per cent.	Al_2O_3 Per cent.	CaO Per cent.	MgO Per cent.	SO_3 Per cent.	Loss. Per cent.
Hanover Portland Cement Co.	46.47	6.97	18.91	7.05	3.97	.26	11.91
Grey and Bruce Portland Cement Co.	37.50	4.79	12.45	19.30	2.96	.16	19.06
Colonial Portland Cement Co. (shale)	44.64	5.65	17.27	9.92	4.86	1.69	13.90
Lakefield Portland Cement Co.	39.58	4.02	11.26	19.86	2.74	.70	18.36
Sun Portland Cement Co.	38.21	3.87	13.93	21.02	2.42	.24	20.36
Imperial Portland Cement Co.	42.26	4.66	12.30	16.08	3.32	.12	18.16
Belleville Portland Cement Co.	51.98	8.94	20.00	1.62	3.33	.20	8.81
Ontario Portland Cement Co.	51.72	5.66	14.11	10.59	3.03	.67	12.14
International Portland Cement Co.	55.92	8.72	18.98	3.64	4.48	.24	3.58
Canadian Portland Cement Co.	51.30	5.55	14.25	7.28	5.31	1.23	11.90
National Portland Cement Co.	66.46	4.25	16.07	1.42	1.85	.23	5.32
Owen Sound Portland Cement Co.	51.04	4.78	11.80	7.32	5.85	2.40	14.12
Superior Portland Cement Co.	44.62	3.54	10.78	17.28	2.70	.23	....
Colonial Portland Cement Co.	44.94	3.90	10.40	12.13	6.72	.56	12.47

EXPLORATIONS IN ABITIBI

BY JAMES G McMILLAN

In accordance with instructions received from Mr. T. W. Gibson, Director of the Bureau of Mines, an exploratory survey was made during the summer of 1904, of that portion of the northern clay belt lying west of lake Abitibi, and north of the area subdivided into townships by the Department of Crown Lands during the previous year.

Practically the whole of this area was, during the past summer, laid out in blocks consisting of four townships each, by meridian and base lines run at intervals of twelve miles, and a portion of the area, consisting of about a dozen townships, was still further sub-divided into lots.

The object of the expedition was to make a careful examination of the surface conditions prevailing in the region, including the geology as exhibited by the rock exposures, and the nature and capabilities—agricultural and otherwise—of the soil, in order that a body of information might be procured illustrative of the economic resources of the district and its suitability for settlement.

The information to be obtained was mainly of two kinds: (1) that connected with the geology and mineralogy of the region, and (2) that bearing upon its suitability for agriculture. The geological and topographical side of the work was in charge of the writer, while the latter was in charge of Mr. A. Henderson, B.A., late of the Ontario Agricultural College, who accompanied the party as agricultural expert, and who reports separately upon this branch of the work.

Besides Mr. Henderson and the writer, the party consisted of O. Mondoux, Copper Cliff; S. Comego, Sudbury, during the first two months in the field; and John L. Lang, Toronto, during the last month and a half.

On June 1st we took the early Canadian Pacific railway train, at Sudbury, for Matagama station, where our canoes were already awaiting us. Two days canoeing up the east branch of the Spanish river brought us to the Height of Land portage, after crossing which we entered the waters which flow to the Mattagami, and in two more days reached Fort Mattagami. After enjoying over Sunday the hospitality of Mr. Millar, the Hudson's Bay Company's factor, and of Mr. Hubert Southworth, chief fire ranger for the district, we again launched our canoes, and in a little over two days reached the first of the portages to Porcupine lake. At this point the work began, which was carried on for nearly four months. The return journey was made from the Frederick House river and Night Hawk lake, by way of Fort Matachewan, down the Montreal river to the Temiskaming and Northern Ontario railway, thence by rail to North Bay.

The plan followed in carrying on the work, was to make trips across country from points along the rivers to one or other of the survey lines, go about two miles along the line, and return to a point on the river where it had been agreed that the canoe should meet us. In this way the rivers were used as highways, and the country traversed at intervals of two or at the most three miles. Whenever the country to be travelled was too remote from the rivers to be reached in this way, a flying camp was moved in to one of the lines, and trips, usually one day in length, made from points on the line to a distance of five or six miles, returning to points two miles farther along the line, camp having in the meantime been moved the two miles along the line by one of the men. On the following day a similar trip would be made on the opposite side of the line, and ending two miles farther along.

Little attention will be paid in this report to the canoe routes used in going from point to point in the district, as they have been described by Dr. Parks, Dr. Kay and others in previous reports of the Bureau of Mines,[1] and also in reports of the Geological Survey.[2]

The report will be divided into four parts as follows :

I. The topography of the area.
II. The features of the separate parts in detail.
III. The resources of the area.
IV. The character of the rocks.

I. TOPOGRAPHY

The area is a plain, in all probability once the bed of a glacial-dammed lake. The only breaks in the general level are, the depressions caused by the erosion of streams, a few isolated hills of the "roche moutonneés" type, and some sand and gravel ridges of a morainic nature, which rise a few feet above the general level. Midway between the rivers of the region are some depressed tracts, once the beds of shallow lakes, but now filled with peat and moss to a depth of 4 to 12 feet. It is in these muskeg areas that most of the tributaries of the larger rivers have their origin. The remainder, comprising at least three-fourths of the whole area, is covered with a uniform deposit of clay and wooded with a mixed growth of spruce, poplar, balm of Gilead, birch and balsam, or almost entirely with spruce, according as the drainage is good or only medium.

Erosion has not gone on to a marked extent. This may be due in part to numerous barriers of rock which cross the rivers at intervals—in no case greater than ten miles—forming natural dams in the streams. Everywhere the valleys have a characteristic V-shape. At a short distance from the rivers, usually about 10 chains, the general level of the plain is reached; while the tributaries entering the main streams have valleys usually not greater than 10 chains in width. At no point is there a valley wider than half a mile.

The northern slopes of the few rocky hills are worn smooth and often striated by the action of the ice; while in the south in their lee, there is in most cases a deposit of sand or gravel extending a short distance from the hill. As the writer's aneroid went out of order, after a month's use, the height of these hills had to be estimated. Most of them appeared to be from 100 to 150 feet above the general level. Glacial striæ, where noted, have a direction between S. 5° W. and S. 10° E. The deposition of the drift materials, however, points to an advance of the ice from a direction about 10° west of north.

The Abitibi River

The Abitibi river flows out of Lower Abitibi lake, in a westerly direction, through the northern portions of the first three townships west of the lake, then forms a great U-shaped bend in the township of Teefy, before taking up its general direction—that of from 10°to 20° west of north. Above Couchiching falls, which are situated about five miles below the outlet of lake Abitibi, the banks are quite low; but below this point, the river has eroded its bed to a depth of 50 to 100 feet below the general level. The highest banks are in the northeast corner of the township of Teefy, where glacial accumulations, of morainic character, have added somewhat to the amount to be eroded; while below Iroquois falls, the banks are somewhat below the average height Throughout this portion of its course, the river maintains a width of 4 to 5

[1] Eighth Rep. B. of M., pp. 175-180; Thriteenth Rep. B. of M., pp. 104-114; Report of Survey and Exploration of Northern Ontario, 1900, pp. 29.
[2] Geol. Sur. Can. Sum. Rep., 1901, p. 119.

chains As far as Couchiching falls the river is quite sluggish; then follow 2 miles of quiet river to the first rapid in lot 1, Knox township, where the fall is less than 2 feet.

From this point to the next rapid on the east side of lot 4 in Rickard, where the fall is 4 feet, and from here again to lot 6 in the same township, where there is a rapid with a fall of 3 feet, the river flows with an even current. These rapids may all be safely run on the left. For ascending there are portages on the same bank, while in addition there is an island portage of 8 chains at the second rapids mentioned. This is the better one to use when the current permits reaching the island. In the western half of Rickard are several rapids with a fall of 1 foot each, joined by stretches of swift water. These may be run with ease, and ascended without much difficulty. This is the only stretch of swift water in the upper portion of the Abitibi. Between this point and the Long Sault rapids, the sole obstructions to navigation are the rapids at the two portages and Iroquois falls, at each of which regular portages are provided on the left bank. The Buck Deer rapids, in concession VI of Aurora township, may be run with care, the only danger being from boulders in low water; and ascended by poling, or by making one or two lifts at the swiftest points.

Frederick House River

From the lower end of Frederick House lake the river of the same name flows, with an average width of about 3 chains, through the central part of the region, in a general direction parallel to that of the Abitibi below the great bend. The country to the north of Frederick House lake is at an elevation of only a few feet above that of the lake; and along the Frederick House river generally the banks have only about half the height of those along the Abitibi. They are highest below the falls in the first concession of Mann, below the three rapids in the fifth concession of the same township, and below Neelands rapids, at which points they have a height of about 50 feet. At most intermediate points the banks have a height of about 30 feet only. As on the Abititbi, the intermediate stretches are of quiet river, with a very moderate current.

The Mattagami

On the west of the area explored, the Mattagami river takes a westerly course for 6 miles from the great bend, just west of the township of Tisdale, in the district of Algoma, then bends again to the north and flows in a direction nearly parallel to that of the other rivers of the region. In the last mile of this western stretch of the river are three rapids, the portages past which are known as the Sandy portages. Above these portages, the banks are low and the current moderate; while below the current is, if anything, less swift between banks of a height of from 50 to 60 feet. The Mattagami is here a beautifully clear river, with an average width of 3 to 4 chains.

In addition to these—the principal—rivers of the region, a large tributary of the Frederick House river, which has not been noted by previous explorers, deserves mention. In its upper part, this river has two main branches; the western of which flows, from the large muskeg area in the townships of Wark and Gowan, as a creek with a width of 20 feet; and the eastern of which has its origin near the southeast corner of the township of Tully. After flowing in a northwest direction for about 12 miles, the first flows in a northerly direction for about 4 miles with a width of 50 to 60 feet, when it is joined by the eastern branch, which here has a width of some 80 feet. About five miles from the junction of these creeks the river is joined by another stream from the east, of about the same size as the smaller of the two. From the junction of the two branches, the river flows in a northerly course, and where next crossed about 7 miles farther north, it has a width of two chains and a depth of 8 feet. It crosses Patten's second base line at 4 m. 24 c., with the same width and joins the Frederick House probably 10 or 12 miles farther down. The

creeks, which drain the greater part of the township between Patten's meridian and the district line, have banks with a height of about 10 feet, and the river below the junction has banks about 20 feet high.

Lakes and Ridges

With the exception of Frederick House lake which is in the area reported upon last year, and lake Abitibi, which forms the eastern boundary of the area, none of the lakes are of sufficient size to form marked physical features. For the most part they are less than a mile in length and fill kettle holes or other depressions in glacial accumulations. Starting near the west bay of Frederick House lake in the township of Evelyn, the most important ridge of glacial material extends for about 30 miles in a direction roughly parallel to and at a distance of 2 to 4 miles from the river. In the southern part the ridge is of sand, wooded with jack-pine and of considerable width. It narrows in the township of Little, and from Beaver lakes near the northwest corner of the township for about 5 miles it is composed largely of boulder clay. A break of 3 or 4 miles occurs about Patten's correction line, after which the ridge can be traced to his second base line. In this part it has a width of about half a mile, with a chain of small narrow lakes and peat bogs occupying a depression within the ridge. The greater part consists of sand; the depressions left by masses of ice which became covered and melted after the body of the ice had retreated, show in places a depth of 60 feet of that material.

At about the same distance east of the Frederick House river a similar ridge, consisting mostly of boulder clay, extends from Speight's base line for about 10 miles in a southerly direction. In the north central part of the first township east of the district line and south of the base line there are several lakes; none however exceed a half mile in length. In the township south of the one just mentioned are several lakes the last one being over one mile long, but very narrow.

In the northwestern part of Calvert township, and extending some distance into McCart is a sand area, at least 2 miles wide, with a number of lakes whose longest axes are in a direction east of north and west of south. Corresponding to this direction the only glacial striæ noted had a direction S. 5° W.

The second largest ridge of glacial material crosses the Abitibi river in the northeast corner of the township of Teefy. It extends in a direction parallel to the two ridges mentioned, as far south as the south townline of Rickard, but only for a distance of about 2 miles north of the river. On the latter side of the river there are two lakes, the largest of which is about 60 chains in length, of beautifully clear water. A portage leads from the river along the gravel ridge to these lakes, which judging by its appearance is much used by the Indians during the hunting season. South of the river are several small lakes, from the more northerly of which a creek has cut through sand to a depth of 60 to 80 feet, and reached the underlying clay.

The largest muskeg area crosses the northern halves of the townships of Wark and Gowan. The only others which exceed two miles in greatest length lie in the west central part of Newmarket, the east central part of Edwards, and the south central part of Moody township.

II. THE REGION IN DETAIL

Speight's Meridian to Mattagami River

The meridian line was reached by ascending a creek about 30 feet in width, which enters the Mattagami river from the north, at the westerly bend of the river. This creek flows out of the township of Murphy, crossing the line at 7 m 60 c., with a width of 15 feet. After ascending the creek for some 3 miles, the line was reached

at 6 m. 60 c., by travelling in an easterly direction across flat clay land wooded mostly with spruce. To the west of the creek near its mouth is a small sand area covered with jack-pine, averaging about 12 inches in diameter.

Along the west boundary of Murphy the country is very level. Though apparently flat and somewhat wet at this season—June 10th—the land is at least 100 feet above the Mattagami river, as indicated by several aneroid readings taken when going out from, and returning to, the river. Miles 8 and 9 cross flat clay land, wooded with spruce averaging about six inches. In mile 10 the clay soil is covered with about 2 feet of moss and mould, and the spruce is rather smaller in size. From 10 m. 40 c. to 11 m. 30 c. the line crosses a muskeg with a depth of peat of at least 7 feet. At 11 m. 55 c. a creek 6 feet wide flows to the west, and this half mile is well drained. For at least 10 c. on either side of the creek, the timber consists of fairly large spruce and poplar, and the clay soil is not moss-covered.

From the 12-m. post on Speight's meridian, a trip was made in a westerly direction to the Mattagami river, which was reached at 8 m. 50 c. The first two miles of the trip cross an area of good clay land, wooded with spruce averaging about 6 inches on the low ground, and with larger spruce, poplar and balsam on the knolls. At 1 m. 72 c. the creek just mentioned was crossed. It here has a width of 8 feet and flows to the northwest. For some distance on either side of our course from 2 m. 20 c. to 2. m. 55 c. the country had been recently burned. This was the only lately burned area seen during the summer, and was of small extent. At the latter distance a creek 15 feet wide was encountered also flowing northwest, to the west of which a rather wet clay area extended for 65 c., followed by 56 c. of muskeg, which apparently extends a considerable distance to the southwest. From 4 m. 16 c. to 5 m. 20 c. the clay soil is covered with about 3 feet of moss and mould and timbered with spruce not exceeding 5 inches in diameter, except for a few chains on either side of a creek 12 feet wide flowing northwest, which was crossed at 4 m. 64 c. At 5 m. 20 c. a muskeg 16 c. wide was encountered, then 64 c. of wet clay land much grown up with black alder, followed by 35 c. of muskeg extending to 6 m. 55 c. These narrow strips of muskeg appeared to be arms of a larger muskeg to the south of our course. At 7 m. a creek 12 feet wide and 2 feet deep flows north through clay land thinly wooded with spruce. At 7 m. 30 c. the larger spruce and drier clay land bordering the river was encountered, and at 8 m. 40 c. the descent to the river began. The bank here is 60 feet high (aneroid) and is wooded with spruce and poplar averaging about 15 inches for some distance back, while close to the river are also balm of Gilead or balsam poplar of 20 inches and cedar of about 16 inches diameter.

The Mattagami Valley

The east bank of the Mattagami was then followed up stream for about 4 miles, in a direction a little east of south. The banks are of clay, with a rise of 50 or 60 feet from the river in a distance of about 10 chains. Rills cut down through the clay at comparatively regular intervals of about 10 chains, but no streams of any note enter the river from the east, and only one, the Kamiskotaia, a river about 1 chain wide, enters from the southwest. The timber along the bank consists of balm and cedar, up to 2 feet diameter, together with spruce and poplar of somewhat smaller size.

The return to camp was made from this point by canoe. About 5 miles up stream, the Water Hen creek enters from the south, and a short distance above the lower of the three portages is reached. This is a sandy portage, 10 chains in length, on the north bank. The middle and upper portages, which are about 32 c. and 80 c. up stream from the lower, are each 20 c. long, and on the south bank. Considerable current is encountered in reaching and in leaving the upper portage. About 10 miles farther up stream the portage to Porcupine lake leaves the Mattagami.

The outcrop of rock at the three portages has been previously described by Dr. Parks. On the north bank of the river at the upper rapids the rock is a porphyry—gray in color. The only additional outcrop seen is on the east bank about 5 miles below the lower rapids. At this point a weathered greenstone shows at the water's edge.

A trip was also made in a westerly direction to the Mattagami river from the 9-m. post on Speight's meridian. For the first mile and a half the soil is a good clay covered with about one foot of mould, and wooded with 6-inch spruce together with a few poplar and balm on the higher ground. The next mile and a half is typical of large areas in this region. The principal tree has been the tamarack, which was killed some years ago by the larch saw-fly. The killing of the tamarack has left the woods rather open to the sunlight, and a thick growth of alder has sprung up among the more or less scattered spruce. Many of the dry tamarack are still sound and would make good wood or ties; but they are decaying at the roots and are being gradually blown down, making with the alder a tangle through which it is hard to pass.

The soil is always clay overlain by 1 to 5 feet of mould. The spruce in these areas is usually somewhat larger than in the regular spruce woods, and the depth of moss considerably less. The only creek is one 3 feet wide flowing south at the end of the first mile. At 3 m. a muskeg 32 c. across was entered. The rest of this mile is wooded with spruce of about 5 inches, and is covered with a depth of 2 feet or more of moss. The next two miles is entirely muskeg with varying depths of peat. At 5 m. a sounding was made by driving down a pointed pole and a sample taken at a depth of one foot. The depth of peat at this point was 6 feet, and at 6 m. the depth was at least 7 feet. In the first half of the 7th mile, the soil is clay deeply covered with moss and wooded with small spruce. This is followed by 24 c. of spruce and poplar, and this in turn by 24 c. of small spruce. From this point to the river which was reached at 7 m. 70 c., the timber is of good size, and the land dry. The white spruce would average 10 inches, the poplar 15, and the cedar and balm probably more.

The river bank at this point has a height of 54 feet (aneroid), and in the gradual slope of the first mile back from the river there is an additional fall of 50 feet (aneroid); so that, the total fall from the level area in the interior to the level of the river is about 100 feet.

The trip was continued from the point on the river just reached, by following the east bank upstream for half a mile, and then taking a course S. 30° E., to the foot of the upper of the three rapids, previously mentioned. The pebbles noted in the beds of the rills here entering the river consist of granite, groonstone, and silicious schist. For the first mile the soil is a good clay, well wooded with the varied timber found along the rivers in the region. At 8 c. on the second mile is a lake 8 c. long, from which a small creek flows to the south. The rest of this mile is level clay land wooded with spruce. At 24 c. on the third mile, a creek 6 feet wide with a bank 30 feet high crosses our course, then turns and follows it for half a mile, when it again turns to the southwest. Tributaries enter this creek from the east at 34 c. and 64 c. The soil is of the same uniform nature, timbered with spruce and balsam. The first 48 c. of the fourth mile is wet clay land, timbered with spruce, averaging 8 or 10 inches, and dry tamarack. Then the land rises about 20 feet, while stony and gravelly soil succeed for a distance of a little over one mile, and balsam and birch replace the tamarack. This is followed by 16 c. of tamarack swamp, when the large timber and dry clay soil of the river margin is entered. At 5m. 24 c. a creek 4 feet wide flows to the west, and at the half mile the foot of the rapids is reached.

The Mattagami river has here a width of about 3 c. and flows almost directly west. To the head of the upper rapids is about 60 c. and the fall in this distance is 12

feet (aneroid). Above the rapids the country has the same general character, but is at a less elevation above the river. After one hour's good paddling in an easterly direction, the river again bends to the south, at the point where the creek ascended at the beginning of the trip enters from the north, and in a little less time the first portage to Porcupine lake is reached.

Wark Township

Two trips were made through this township, one on the west and the other on the east side, from Speight's base line, which forms the southern boundary.

Travelling north from the 12-m. post on Speight's meridian, the first 60 c. is muskeg, and the rest of the mile clay land, timbered with spruce and poplar. The next 20 c. is quite mossy and covered with scrubby spruce, then follows one mile of good clay land wooded with spruce, dry tamarack and alder, with some poplar on the knolls. At 2 m. 20 c. the land becomes a little higher, and spruce and poplar woods follow to the end of the mile.

The fourth mile passes through a typical spruce woods, with timber averaging 6 inches. The soil is a good clay under one foot of moss and a varying depth of mould. At 42 c. and at 70 c. creeks of widths of 6 and 4 feet respectively, flow to the west. In the fifth mile, the first 35 c. have a depth of 5 feet of peaty mould and scrubby spruce timber. This is followed in turn by 5 c. of poplar knoll, 10 c. of muskeg open to east and west, 10 c. of spruce knoll and 50 c. of muskeg, with a depth of 6 feet of peat. The remaining 50 c. of the sixth mile is level clay land, timbered with 5-inch spruce and poplar. At 5 m. 55 c. a creek 5 feet wide flows to the east.

Travelling eastward from this, the northwest corner of the township—the first 60 c. is good clay land covered with about 2 feet of moss and mould, and a good growth of 9-inch spruce. At 75 c. a creek 15 feet wide and 4 feet deep flows to the north, and at 1 m. 65 c. another of 16 feet width and 2 feet depth flows to the northwest. The land between these two creeks is equally good, but the timber is much smaller, averaging about 5 inches.

Turning in a southerly direction at a point 2 miles east of the corner mentioned, the same creek is soon crossed a second time. At 15 c. a muskeg 25 c. wide is entered, and at 54 c. a creek 40 feet wide is noted lying just to the east of our course. This is probably the same creek dammed by beaver, as on a creek 6 feet wide flowing east at 67 c. beaver cuttings are quite plentiful. Along these creeks the timber consists of 6-inch spruce and 14-inch poplar, growing on a good clay soil. Then follows half a mile of the same spruce, on a good clay soil covered with about one foot of moss. At the half mile, 10 c. of poplar knoll is encountered, the rest of the mile being of the same character as the first part. In the first half of the third mile, the spruce is small and the depth of moss about 3 feet. From 2 m. 40 c. to 4 m. is a large muskeg, open for at least 1 mile to the west and having a depth of at least 9 feet of peat. At 3 m. 50 c. a blazed trail bears S. 50° E., probably to the Porcupine river, as a similar trail was noticed leaving one of its branches. In the first half of the fifth mile the spruce is small and the land wet; then follow in turn 20 c. of muskeg and 50 c. of spruce and poplar woods and dry clay land. A creek, 10 feet wide, flowing east at 5 m. drains this area. From 5 m. 30 c. to 5 m. 60 c. the soil is a good clay with a growth of 10-inch spruce. From this to the line, which was reached at 2 m. 40 c., the spruce is very scrubby and the moss deep.

The east half of the township was explored by travelling along the south boundary to the 6-m. post on Speight's line, and making a trip similar to the last 6 miles north from this point.

A hard green schist, containing some quartz stringers, outcrops along the line at 2 m. 55 c. and at 3 m. 8 c. Near the 4-m. post is another outcrop of similar rock,

with some layers quite soft and dark in color. At 4-m. 12 c. low rocky ridge extending some 14 c. to the north, has much the same nature, but in places has the appearance of a tuff or ash rock.

The land between these two outcrops is composed of good clay soil, drained by a creek seven feet wide, flowing north at 3 m. 28 c. From the last outcrop to the 6-m. post, the soil is mostly clay. At 50 c. cn the fifth mile, the line crosses a sand knoll 15 c. across; and at 12 c. on the sixth crosses a creek 16 feet wide flowing southeast.

Going north from the southeast corner of the township, the first mile is dry clay land with here and there granite and greenstone boulders. In the second mile the first half is lower and wooded with small spruce only, and the last half muskeg. In the third mile, the first 35 c .are wet and the spruce small. This is succeeded by one mile of clay land, wooded with 6-inch spruce, and covered by 1 foot of moss. Then follows 80 c. of muskeg, which extends to a considerable distance east and west. A sounding taken at 4 m. gave a depth of peat of at least 7 feet. The spruce woods extending to the north of this area, contain trees averaging 6 inches. The last 30 c. of the sixth mile pass through another muskeg, with a depth of peat of 9 feet, and extending 20 c. to the west. To the west of this the same spruce woods extend for 60 c., then follow 40 c. of muskeg, apparently an arm of a larger one to the northwest. This is followed by a half mile of wet spruce woods, in which the clay soil is covered with about 4 feet of moss and mould.

Turning to the south after travelling two miles westward, the first 100 c. is good clay land covered with 1 foot of moss and mould, and wooded with 5-inch spruce. At 27 c. and at 54 c. creeks 3 feet wide flow to the west. Along these creeks the spruce is much larger and is mixed with 12-inch poplar. The next 100 c. up to 2 m. 40 c. is muskeg, with a depth of peat of 7½ feet. South of this muskeg the land slopes very slightly to the south. The soil is a good clay covered, except along the creeks and on the knolls, with about 1 foot of mould. At 4 m. there is about a quarter of a mile of wet land with 6 feet of moss and mould, and timbered with small spruce; but over the rest of the area the spruce would average six or seven inches in diameter. The poplar growing along the creeks and upon scattered knolls would average 12 inches. At 5 m. a creek 16 feet wide and 2 feet deep, which drains the south half of the township, flows to the southeast, while a branch 4 feet wide enters it from the north. At 3 m. 50 c. another creek 3 feet in width flows to the east. After passing through half a mile of spruce and poplar woods the line was reached at a point 8 c. east of the 4-m. post.

A Muskeg Area

The northern half of the township of Gowan is very similar to the same portion of Wark. A muskeg with a depth of peat varying from 4 to over 9 feet stretches from west to east across the two townships. This was crossed from north to south at intervals of 2 miles. Two miles from the east boundary of Gowan the width was two miles and a half, and the depth from 5 to 6 feet. At the same distance from the west boundary of Wark, the width was one mile and a half, and the depth over 9 feet. At the other four points the width was a mile and a quarter.

Where the depth of peat exceeds 4 feet, these areas are practically open. Though scattered spruce and tamarack of an age as great as that of any trees in the region are found upon them, they rarely exceed 15 feet in height, or 3 inches in diameter. Many spruce were seen with 150 annual rings and a diameter of 2 inches. Together with these scrubby trees there is, in many places, a dwarf birch which is a mere shrub from 2 to 4 feet in height. In June the previous year's berries were still fresh upon the cranberry bushes.

This muskeg is the source of some important streams. Mention has already been made of the creek flowing out of it to the north, which, after some miles, forms a considerable river. Two at least and possibly three creeks of a width of 15 feet flow out of the northwest corner, and must before they reach the Mattagami river form a stream of considerable size. From the south side the drainage is to the Porcupine river. Besides the creek previously mentioned as flowing to the southeast through Wark, a creek 10 feet in width also flows into the north branch of the Porcupine from the west side of Gowan, while from the east side a creek 16 feet in width flows south into the Porcupine below the junction of the north branch with the main stream. Upon the upper part of the last mentioned creek a beaver dam 5 feet in height was seen and in fact on nearly every stream beaver cuttings and work are plentiful. These last two creeks drain an area in every respect similar to that in the south of Wark township.

Spruce Forest

To the north of the area just described, and in the townships of Prosser and Tully, is an extensive area of spruce woods. The timber averages from 6 to 10 inches in diameter, the larger size being found along the creeks where there are a few poplar mixed with the spruce. The trees are young and thrifty, and the woods remarkably clean and free from windfall. In the parts remote from the creeks, the best timber is found in the third concession of Prosser, where the spruce averages from 8 to 10 inches in diameter. In this part the soil is covered with a depth of 2 to 4 feet of moss and mould; but over the greater part of the area there is only sufficient moss to form a carpet for the ground.

The creeks which flow in a northwesterly direction from the centre of the southern part of Tully are very little below the level of the area. The average width of the larger stream is about 20 feet in the second concession of Tully, where it flows through lot 8. This increases to about 30 feet where it leaves the township of Prosser on the east side of lot 5. The more easterly stream has, in lot 5 concession IV, Tully, a width of about 12 feet; while between lots 8 and 9, where it leaves the township the width has increased to nearly 30 feet. Beaver dams in many places give this stream a width of over 20 feet, and the larger a width of 50 to 60 feet.

Though the banks are only a few feet high the land is, for the most part, fairly dry and the soil a uniformly good clay. A ridge of sand and gravel about half a mile wide runs east and west through the fourth concession of Prosser, for at least four miles in the middle of the township. The timber on this ridge consists of spruce and birch, averaging 12 inches in diameter, and poplar averaging 18.

Muskegs are not extensive within the area. Lots 4 and 5 in the sixth concession of Tully have a depth of peat of about 6 feet, and in the other lots in the northeast corner of the township there is also considerable muskeg. About half of lot 8 in the fourth and fifth concessions have a depth of 4 feet of peat.

The only muskeg seen in the township of Prosser was one in lots 4 and 5 in the fifth concession, which had a width of about 35 chains.

Rock Outcroppings.

Several outcrops of rock were noted within this area. In lot 5 in the third concession of Tully several ridges, from 10 to 30 feet high, run east and west. The rock is a much weathered greenstone, fine-grained in structure, and showing the presence of decomposition products. In the southern part of lot 8 in the second concession of Prosser, there is a hill, about 120 feet high, the central portion of which consists of breccia, while the sides are flanked by an iron-stained schist, grey in color, with a strike of N. 70° E., and a dip about 75° to the north. A green schist outcrops in the northern part of the same lot in the third concession; and

within about 10 chains of the northwest corner of the township another outcrop of schist rather lighter in color occurs. These have the appearance of altered greenstones.

The boulders noted within the ridge previously mentioned comprise greenstone, granite and schists of much the same character as those within the area. In the bed of the larger creek where it flows out of the township, a pebble of greenstone containing considerable pyrrhotite was noted.

Patten's First Base to His Correction Line.

This is an area of uniform clay land, but of quite varied timber growth. The latter feature is largely due to a considerable part of the area having been burned over—the larger portion some 40 years ago, and a smaller portion about 10 years ago. The opening produced by these fires has led to the extensive windfalls in the adjoining timbered parts.

The largest area of windfall surrounds the 12-m. post on Patten's meridian. This extends for nearly 3 miles into the township of Prosser, and for over a mile north from the boundary. A trip west from this post showed that tamarack windfall extended for about 3 miles in that direction, but a mile north of this fairly good spruce of 6 to 9 inches in diameter grows quite free from tamarack. This area is mostly of wet clay land, and in this part the dead tamarack only are blown down, leaving thin spruce woods; but on the higher land many balsam and some spruce in addition to the tamarack have been uprooted.

Another windfall area extends for about 2 miles along the creek which flows to the northwest from the township of Tully. This area reaches east to a muskeg in lot 5 of the sixth concession of Tully, but not over half a mile to the west. The creek through this part has a bank from 8 to 10 feet in height, but the land is at almost a dead level. As a result the natural drainage is not good.

At the point where the larger of the two creeks crosses Patten's base line, the land has an elevation of some 30 feet above the level of the creek. This dry clay area extends along the creek with a width of over a mile, for at least 1 mile straight north and for nearly the same distance south into Prosser. The timber is of no value, as it consists of scattered brushy spruce of about 40 years' growth; but the soil is a good clay, fairly well covered with grass where the trees are very scattered.

Along the same creek to the northwest of this area, a brulé of 10 years extends for about 2 miles. Where crossed in going east from the 14-m. post on the meridian line, it has a width of over a mile. Part of the same brulé crosses the meridian just north of the 14-m. post with a width of 32 chains. This area is commencing to grow up with young spruce, poplar and tamarack.

The portion of the area lying along the Correction line for the whole 12 miles, along the creeks through the northern part of the area, and between these to within a short distance of the base line, is mostly spruce woods. For a quarter of a mile along the creeks the spruce is large, some reaching a diameter of over 2 feet; but over the greater part of the area the average diameter is from 8 to 10 inches. The soil throughout is clay covered with a depth of moss and mould varying from 1 to 3 feet.

A trip west from the 16-m. post on the meridian line for a distance of 3 miles crosses a similar area. From near this post a creek 12 feet wide flows east to join the west branch which is here about a mile distant. About 2 miles west a creek of the same width, but increasing to 20 feet in width a mile to the west, flows in a northwesterly direction to the Mattagami.

Along this latter creek the spruce averages 1 foot in diameter, and the soil is fairly dry; but over the rest of the area west of miles 17 and 18 the spruce averages from 6 to 8 inches, and the soil is covered with 3 to 4 feet of moss and mould.

The muskegs, though larger than in the spruce woods to the south, do not comprise much more than one-twentieth of the whole area. At 13 m. 40 c. on the meridian line a muskeg crosses in an east and west direction, with a width of some 30 chains. North of lots 1 and 2 in the sixth concession of Prosser there is a muskeg probably about 300 acres in extent, while in the third and fourth miles north of lot 4 in the same concession there is another of about a square mile in area, from which three creeks with widths of 4 to 10 feet flow east to join the east branch. About 3 miles east from the 16-m. post on the meridian is another area a mile in width. Three miles north of the 8-m. post on the base line a muskeg with a width of 50 chains was crossed, while in the northeast corner of the area is the only other of any considerable area in the part east of the smaller branch. The depth of peat in each of these muskegs is about 6 feet.

In the eastern part of the section, the area of glacial accumulations which extends from Beaver lakes to a point on the Correction line midway between the two lakes in the third mile, forms a divide between the basins of the Frederick House and of the streams of the section. The soil is a good clay mixed with a considerable proportion of sand; and the land has a sufficient relief to be quite dry. The timber growth is about 40 years old and consists of poplar and balm of 8-inch size, and a thick growth of small spruce, except between the two lakes mentioned where the timber is of greater age, the poplar having here a diameter of 16 inches.

The only rock seen within the section outcrops just east of the brulé at a point about 3 miles northeast of the western end of the base line. This is an altered greenstone with a peculiar granular structure, probably due to the weathering of the original constituents.

The Basin of the Mattagami

For the next 12 miles north to Patten's second base line, this stream flows through an area of clay land superior in respect to drainage to those previously described. The difference in level of 15 to 20 feet between the bed of the stream and the plain is sufficient to drain the country in its present condition for some 2 miles on either side of the river. In the northern half of the basin, where the slope is somewhat more marked, the clearing of the land would no doubt provide good drainage for an area twice as large.

In the southern half of this portion of the basin, the timber is of little value for about 2 miles on the west side of the river. This part was burned over some 40 years ago, and is now covered with a thicket of young spruce and tamarack, except in the swales, where some of the original spruce timber remains.

The 21st, 22nd, and part of the 23rd miles on the meridian line pass through spruce woods with timber averaging 6 or 7 inches in diameter. About the 23-m. post there is a muskeg probably a mile in length with a depth of peat of 4 or 5 feet, while two miles east of the 22nd mile there is another of about the same size with 5½ feet of peat.

Along the east branch, which forms a junction with the main stream about 2 miles north of the 9-m. post on the Correction line, the spruce is of an average size of 12 inches. In the area between the two branches however the spruce is smaller, averaging probably 8 inches in diameter.

The only glacial accumulations seen in the southern portion of the area were crossed 5 miles north of the fourth mile of the Correction line. Two lakes were seen here, one quite small, filling a kettle-hole, and one half a mile in length, apparently with an outlet to the northeast. At five miles north of the 4-m. post, a muskeg apparently occupies a depression within the accumulations, since for half

a mile to the south there is the same slightly stony clay soil, with a marked southern slope. Upon this soil the spruce and poplar grow very large, some reaching a diameter of 2 feet.

Between these glacial deposits and the Correction line is an area of spruce woods, with muskeg half a mile in width in the northern halves of the second and third miles from that line. A creek, which crosses the Correction line at the 4-m. post with a width of 12 feet, and which flows north and turns to the northeast with a width of 20 feet at a distance of one mile from the line, one 20 feet wide flowing west 2 miles from the line, and a third 15 feet wide flowing out of a small lake at a distance of 3 miles 24 chains from the line, drain this area, and in all probability together form a large stream entering the river at some point midway between the Correction and Base lines. This area is quite level, and is timbered with spruce averaging from 6 to 8 inches in diameter.

In the northern half of the basin, in addition to the ridge of glacial material which forms the divide on its eastern side, there is a second ridge crossing the base line at the 6-m. post. West of this ridge is a small lake, followed by half a mile of sand timbered with thrifty young poplar and birch one foot in diameter.

Along the Base line from this sand area to the river and for 2 miles to the west the timber is of little value, consisting for the most part of young brushy spruce, together with some poplar and birch on the higher ground. The rest of the northern half of the basin, excepting the muskeg portions, is covered with good spruce, poplar, balsam and birch of about 70 years' growth. The first largely predominates in the parts at a distance from the river, while poplar is the chief timber close to the streams. The latter two occur to a lesser extent on the higher ground.

Narrow strips of muskeg occur quite frequently, but few of them exceed 15 chains in width. The largest crosses the Base line in the middle of the first mile and meridian at 24 chains on the thirtieth mile, with a width of about 48 chains, and a depth of peat of 7 feet. The middle of the 28th mile on the meridian is occupied by a muskeg about half a mile across. Three miles south of the middle of the 7th mile on the Base line there is a marshy lake about 60 chains long, lying in a north and south direction, and about 20 chains in width. A creek 16 feet wide flows from the northwest corner. On the east side of this lake there is a mile and a half of good spruce, averaging 8 inches in diameter, while to the west there is 30 chains of muskeg.

The only outcrop of rock noted occurs in the third mile north of the 8-m. post on the Correction line. The rock appears to be a syenite. It is very much weathered and the dark minerals of the rock are greatly altered.

The Frederick House Basin

This basin was explored from Frederick House lake to the base line run east and west from the 162-m. post on the district line, a distance of 24 miles north and south. It has been pointed out that the western portion of the basin is small, varying from 2 to 4 miles in width. The eastern portion has nearly a uniform width of about 6 miles. Three important tributaries enter the river in the northern half of this portion of the basin, one from the east and one from the west near the 156-m. post on the district line, and the third from the east at a point about 3 miles farther up stream. The only large stream, entering the river in the southern half, drains the township of McCart, and joins the river with a width of about a chain to the north of an island in the river about 2 miles below the outlet of the lake.

The largest creek in the western part of the basin has its source in a lake about half a mile long which lies immediately west of the 2-m. post on the Correction line, and in a wet clay area to the east of this lake. It flows north for about 2 miles,

then bends to the northeast with a width of 15 feet, and crosses the district line in the 155th mile with a width of some 30 feet. The area drained by this stream has a good clay soil covered with from 1 to 2 feet of mould, and with a timber growth consisting mostly of spruce. Along the Correction line, the timber averages 10 inches, and along the middle portion of the creek from 6 to 8 inches in diameter, with considerable tamarack windfall throughout.

From this stream north to the base line, the soil is of the same character, but higher and well drained. The timber growth is of mixed kinds and of a good size. A section of this area at a point about 2½ miles from the base line showed over a mile of this timber along the river on the west side.

On the opposite side of the Frederick House, a trip made from Neelands rapids to the 162-m. post, showed the presence of about the same width of mixed timber, followed by spruce woods to within a half mile of the corner, where the wet clay land changes to muskeg. On the east side of the district line there is almost another mile of 10-inch spruce. A trip inland from near the point where this line crosses the river was made through a narrow margin of mixed timber and a mile and a half of 8-inch spruce to a muskeg 30 chains wide opening out to the north.

The largest of the three tributaries probably has its source in a muskeg situated one mile west of the middle of the east boundary of the first township south of Speight's base line, and east of the district line. It flows about 2 miles west, when after being joined by branches which drain the northern part of the township it turns sharply to the south for three miles, leaving the township near the middle of the south boundary with a width of one chain. A short distance above this point it is joined by a creek 15 feet wide flowing out of a series of lakes which lie about 4 miles east of the district line in the southerly one of the two townships. For the lower 4 or 5 miles of its course, the creek makes a big bend to the south into this township, joining the Frederick House near the point where the north town line will cross that river.

The eastern two-thirds of the more northerly townships is another of those areas which have been burned over. The timber is of little value, consisting for the most part of a thicket of spruce and tamarack of about 40 years' growth. About the middle of the east side of this township there is a considerable area of high land wooded with thrifty mixed timber of remarkable growth. Some of the poplar with 40 annual rings have here a diameter of 14 inches. Over almost the whole of the area the soil is a good clay, and for the most part the land is dry.

The land along the lower 5 miles of the last-mentioned creek has also a good clay soil, but it is much lower. The timber is mostly spruce, which along the creek will average 12 inches in diameter, but at a distance therefrom is considerably smaller. To the east of the bend in the creek, an extensive windfall has practically destroyed the timber. To the west of the middle one of the three lakes mapped, there is a mile of large poplar and birch timber on high clay land, which is probably a remnant of one of the glacial ridges of morainic origin.

In all other respects, except in size and in direction of flow, the third of these tributaries is a duplicate of the last. It has its source in a large muskeg about 2 miles west of the centre of the township of Newmarket, and flows in a northwesterly direction, crossing the north-east corner of lot 3 in the fourth concession of Mann, and Galbraith's base line at a point 10 chains west of the 4-m. post. It is about one-third the size of the more northerly stream. Below the Base line the timber consists of spruce of 9 to 12 inch size, balsam and balm. Above this line, for a width of 3 miles along the creek, the timber is second-growth of the same character and age as in the areas previously described. The largest of these spruce trees have a diameter of 6 inches.

Between the 144th and the 150th miles on the district line, the Frederick House river flows within about 2 miles of the western side of its basin. The soil in the western part of the basin at this point is a somewhat gritty clay and quite dry. The timber is second growth of no value, some of the poplar only reaching a size of 8 inches. This area of second-growth timber is connected with the one in the northeast part of Mann by a strip of the same about 60 chains wide in the fourth concession of that township. Beaver lakes have been described by Dr. Parks in the 1899 Report. The only lakes seen in this part in addition to these were two V-shaped lakes 20 chains in length situated at distances of one and two miles respectively to the north of Beaver lakes.

For a distance of about one mile from the river on the east side the timber is of a mixed character, being young and not very large. The poplar and balm average about 1 foot, and the spruce 8 inches in diameter. At a greater distance from the river the timber consists mostly of 8-inch spruce. The only land not suited for agricultural purposes is a muskeg area about a mile across one mile west of the southeast corner of Mann, and a small rocky area in the second mile north of this point.

The southern portion of the basin has a width to the west of the river of between 2 and 3 miles, and to the east of about 6 miles. A ridge of white sand, running from the middle of the south boundary of Little towards the northwest corner of that township, forms the divide on the west. Between this ridge and the river for 2 miles north of the south boundary of Little the land is quite swampy and thinly timbered on account of the number of dead tamarack. Part of this area, which was almost entirely tamarack, has a fair growth of hay. From this point north to the falls in the township of Mann, the land is higher and the timber of better quality. For a distance varying from a quarter to half a mile from the river the timber is largely chains wide. The land between this muskeg and another of about the same width diameter. At a greater distance from the river the timber is mostly spruce of 6 or 8-inch size, and when poplar is present it does not average over 10 inches in diameter. On the east side of this sand ridge in lot 9 of the fourth concession of Little there is a muskeg over half a mile in width with 10 feet of peat in the deepest part, which has in part at least a sand bottom. On the east side of this ridge in the first concession of the township there is also a muskeg with about half this width.

For a distance of 2 miles along the south boundary of Little from the southwest corner there is an area of sand covered with small jack-pine, which extends nearly half a mile from the line. On the north and east sides of this area is a muskeg 30 chains wide. The land between this muskeg and another of about the same width west of the jack-pine ridge first mentioned consists mostly of swamp wooded with 7-inch spruce, tamarack and scrubby cedar. This part must be considered of little value for farming purposes, on account of the amount of sandy soil and of muskeg with sandy bottom.

On the east the divide between this part of the basin and that of the Abitibi is formed by an area of sand lying mostly in Calvert township. This is the largest sand area in the region explored. It covers nearly all of the four western lots in the northern half of the township, and part of the east side of the adjoining township of McCart. Granite and greenstone boulders are scattered over the surface in many places, and quite a number of narrow lakes fill depressions in the sand. The soil is of little value, but the area is fairly well wooded with tie-timber, mostly jack-pine averaging a foot in diameter.

Several creeks rise in small lakes in the southern part of this area, or in muskegs adjoining, and flowing west form a creek 50 feet wide in the middle of McCart. A mile farther west this large creek is joined by another which flows in a southerly direction from the northwest corner of the township with a width of 8 feet.

and empties into a lake half a mile long near the junction of the two streams with a width of 20 feet. The combined stream flows west through the second concession near the south end of the lots and enters the Frederick House north of the island in the river, with a width of about a chain.

Good Spruce and Birch

The land drained by these streams is the best timbered portion of the Frederick House basin. Over the whole area the spruce will average 10 inches in diameter, while about the junction of the two streams is a very fine area of birch which will average 18 inches. This grows on two ridges, which are probably moraines, one to the south of the junction and the other between the two streams. The more southerly one has a steep slope to the north and a height of about 60 feet. With the exception of these stony areas the soil is good.

Along the boundary between Little and McCart, there is mixed timber in the second concession, and in the third spruce from 6 to 12 inches in diameter, while the fourth is muskeg, with a depth of 8 feet of peat. A trip inland from the river along the tie-line showed in this part of Little, a narrow margin of poplar and balm, followed by good-sized spruce to the muskeg near the east boundary of the township.

Rocks on the Frederick House

The rocks outcropping along the Frederick House river have been described in a previous report by Dr. Parks.[3] These may simply be enumerated here as follows:

An outcrop of mica schist at Neeland's rapids.

Diorite and a fine-grained schist below the three portages.

A serpentine rock at the three rapids.

Diorite, diorite porphyrite, and a fine gray silicious schist at the falls.

In addition to these the following outcrops were examined within the river basin:

A short distance up the large tributary which enters the Frederick House from the east, there occurs an outcrop of schistose greenstone with glaciated surface, the striæ running S. 10° E., which proved upon examination to be a weathered gabbro.

In the middle of lot 2 on the north boundary of Mann there is an outcrop of hornblende granite, which is badly weathered on the surface.

A weathered greenstone in which aggregates of serpentine and considerable magnetite are plainly seen, outcrops between lots 8 and 9 in the fourth concession of Mann. This is evidently a rock of the same character as that at the rapids, a couple of miles distant, on the river.

At distances of 14, 24 and 40 chains, respectively, on the line running north from the post for lots 2 and 3 in the first and second concessions of Mann, there are low ridges of diorite. The soil between these ridges is stoney, with boulders of augen-gneiss and greenstone scattered over the surface in places.

A ridge of eruptive greenstone, a quarter of a mile in width, crosses Speight's tie line in lot 7, and runs north of the post between lots 4 and 5 on the north boundary of McCart. Samples of a very similar rock were brought in by Mr. Henderson from a high hill on the south boundary of the township in lot 6.

A bluish quartzose schist, rusty in places, and containing pyrite, magnetite, and a white mineral—apparently a product of decomposition—outcrops on the east side of lot 10 at a point 16 chains north of the line between concessions one and two of the township of Little. The strike of this rock appeared to be about N. 10° W. Diorite schist was seen at a point about 30 chains south of the last outcrop, but whether this was in place or only a loose mass could not be determined.

3 Eighth Rep. Bur. Mines, p. 178.

On the Frederick House river between the lake of the same name and Night Hawk lake two outcrops which have not been reported occur on the east bank at distances of two miles above the first and of two miles below the latter lake respectively. These rocks consist of green schist, the one nearest Night Hawk lake containing large crystals of pyrite.

The Abitibi Basin

The basin of the Abitibi differs from that of the Frederick House, mainly in being at a greater elevation above the level of the river. As a result, the creeks tributary to the Abitibi have cut deep ravines to distances from the river varying from 2 to 7 miles according to the size of the stream. This is particularly true of the central part of the basin, where the creeks entering the Abitibi below Iroquois falls have ravines from 60 to 100 feet deep at distances of a mile or more from the river, while the Misto-ogo river and the large creek a short distance to the west at distances of 6 or 7 miles in a straight line from the river have ravines 30 feet deep.

A Well Timbered Region

This, coupled with the fact that the trees are here of greater age, has led to a much better growth of timber than in the parts previously described. The mixed timber, consisting partly of poplar and balm and partly of spruce and balsam, which rarely reaches to more than half a mile from the Frederick House, extends on either side of the Abitibi for an average distance of 3 miles.

The poplar and balm are fine timber of their class. The trees are thrifty, from 60 to 80 feet in height, and sometimes reach a diameter of 3 feet. The average diameter noted varied from 15 to 20 inches. Probably in the portion of the basin covered with this class of timber, 18 inches would be about the average. The spruce grows to a greater height but rarely reaches a diameter exceeding 2 feet. The average diameters noted for this tree varied from 12 to 16 inches, the larger dimensions being found in proximity to the streams. The relative size of the spruce to that of the other timber would be as 15 is to 18. The balsam have a slightly less diameter than the spruce, and a height about equal to that of the poplar. Some cedar grows along the river banks, but it never attains a great height and tapers rapidly from the rather large diameter of 12 to 18 inches at the butt. It will be of little value except for fence posts.

In the southern tier of township from Calvert to Knox there are extensive windfalls, which lessen the value of the timber to a considerable extent. The timber which has suffered most from the violence of the wind is the balsam. These trees are easily uprooted and in some of the more exposed parts almost all are overturned. Where this is the case many of the other trees are either broken off or uprooted, and in some parts only isolated poplar or spruce remain. These open areas are grown up with a tangle of second growth, berry bushes, mountain maple and alder. Travelling across these areas is very laborious, but in season there is many a delicious handful of raspberries, gooseberries and red currants as a reward for the pedestrian's toil.

Good Clay Soil

Over almost the entire basin the soil is a good quality of clay. For the greater part of the three miles on either side of the river, it is well drained by the many creeks which have cut channels at right angles to the course of the river. At a greater distance from the river than this, there are several areas of wet clay land. These areas are not of a less elevation than the well-drained parts; but on account of their level nature the water does not readily flow off them, at least in their present timbered condition.

In the upper part of the basin, between Couchiching falls and lake Abitibi, though the land is comparatively flat, it is well adapted for farming. The poplar and spruce on the north side of the river average about 15 inches in diameter.

The Dokis River

The largest tributary in this part, which is called the Dokis river by some because a hunter named Henry Dokis lives in a log cabin near its mouth, crosses Robertson's base line at 4 m. 30 c. with a width of 20 feet, and flowing north joins the Abitibi with a width of 60 feet near the centre of the township. This stream, which is navigable for about half the distance to the base line, flows through good clay land wooded with 16-inch poplar and balm, and 12-inch spruce.

Another large tributary rises near the southeast corner of the township, and flows north to join the Abitibi about a mile east of the other with a width of 50 feet. A trip to the river a short distance east of this stream showed the presence of large poplar, balm and spruce for the last 2 miles. Two smaller streams which are navigable for only short distances enter, one on either side of the river, about a mile west of the first.

On the point to the east of the outlet of Abitibi lake there is an area of red pine, covering between a quarter and half a section. This is the largest area of red pine in the region.

The shore of the lake about the outlet and for two miles to the northwest is quite sandy. About the head of the bay to the north of this, which is two miles wide, is an area of dry tamarack, which appears to be low and swampy. Between this large bay and the next, four miles to the north, the shore is stony and wooded with mixed timber, with the exception of two small areas of spruce flat about two intervening bays. Between this bay and the point where Galbraith's base line meets the lake, the shore is rocky. Glacial striæ, running S. 15° E., are shown on a small island of greenstone about 2 miles out from the end of the line.

At the north end of the projecting point to the southeast of the line there is a chlorite schist striking west, and a small island of sericite schist off this point. Green schist outcrops near the end of the line and at 41 m. 30 c. there is an outcrop of massive greenstone.

The first three miles north of the Abitibi river along Galbraith's first base line is good clay land wooded with mixed timber of large size, in which there is some windfall. The next 60 chains passes through a muskeg with 8 to 9 feet of peat. North of this is 60 chains of land similar to the first 3 miles. In the northern half of the 50th mile the line crosses a beautiful clear water lake about half a mile in length, which is surrounded on the south and west by a sand area timbered with jack-pine of 12 to 16-inch size. A creek with highly ferruginous water flows from a small quaking bog a short distance north of the lake. The only probable source of the iron appeared to be pyrites in the surrounding sand. The next two miles are of rather poor character as far as soil and timber are concerned. Several low ridges of sand run east and west through spruce swamp, with a sand bottom. These have the appearance of having been formed on the shore of a lake.

Small dips were noted at several points in this swamp, the largest being 12°, but nothing capable of influencing the needle was seen.

The Dokis river flows east along the base line for two miles, then turns sharply to the south along the meridian for over a mile before turning again to the east and crossing that line. It has here a width of 20 feet; but must increase rapidly in size, as it is reported to have a width of nearly two chains where it crosses the base line in the 40th mile. The spruce in this part averages 6 inches, and the poplar where present only 8 inches in diameter. A few large spruce—evidently first-growth timber—occur close to the stream.

Greenstone Ridges

The southeast corner of the township of Knox is broken up by ridges of greenstone which run nearly east and west. Several low ridges cross the meridian for a quarter of a mile on either side of the 43-m. post, while another outcrop occurs at the 44-m. post on that line. Several outcrops also occur, at intervals of half a mile or less, on the south boundary of the township in lots A, 1, 2, 3 and 4. Near the northwest corner of lot 4 in the first concession the same kind of rock forms a hill nearly 200 feet high. Nearly half a mile north of this hill still another outcrop was seen.

This greenstone varies somewhat in the different outcrops, but is evidently one eruptive mass. It contains considerable pyrite near the 43-m. post on the meridian, and stringers of quartz near the 35-m. post on the Base up to this line. In some places it is distinctly schistose, while in other parts no trace of schistosity is seen.

The soil is composed partly of low sand ridges and partly of level clay land. The 36th mile on the base line in almost entirely clay, wooded with large mixed timber. A photograph was taken of some fine poplar in this mile. The other miles along the meridian and base lines are more broken, but there is some good land in each. The two miles of country between this rocky area and the Abitibi, with the exception of a small area of sand surrounding two little lakes on the meridian, has a good clay soil and is wooded with marginal timber of large size.

In the first mile north of the greenstone hill in lot 4 there is considerable balsam windfall.

A large creek flows from this area in a northwesterly direction to join the Abitibi in lot 5. Where crossed at a point one mile distant from the river, it flowed in a ravine 30 feet deep and had a width of 12 feet.

A second creek, identical with the last in respect to size and depth of ravine flows from the eastern side of Rickard township, and joins the Abitibi in lot 11 of Knox. The first two and a half miles south from the river are marginal in character, and the remaining 2 miles to the boundary are level spruce land. The soil is clay throughout. The presence of rounded stones and gritty material within the clay at a distance of half a mile from the river, points to part of it at least being of glacial origin.

On the south town-line of Rickard, the first mile east of the centre is mostly muskeg with a depth of 8 feet of peat. From the middle of this mile north to the Abitibi at the foot of the Crooked rapids the country is similar to that on the east of the township. The spruce in the first 2 miles is somewhat larger, varying from 6 to 12 inches in diameter, and in the next mile and a half the windfall is more extensive than on the eastern side of the township.

At this point a ridge of greenstone, running east and west, was crossed, and from here to the river the timber is very large, the poplar averaging 20 inches and the spruce 16 inches in diameter. About a quarter of a mile below these rapids, a creek of 20 feet enters the Abitibi on the south side. This creek has produced a ravine of much greater depth than the other tributaries above. In the bed of this stream at a distance of 8 chains from the river another outcrop of greenstone occurs.

On the west side of Rickard a ridge of glacial material extends, from lot 10 in the first cocession, across the meridian in the fourth mile and the Abitibi river in the northeast corner of Teefy, into the township of Edwards for a distance of over a mile. There is a narrow lake, half a mile in length, with an outlet to the southwest at the south end of the ridge. That this ridge, which is quite low at this point, has along the meridian a height of about 70 feet, is shown by the depth to which a small creek which drains two or more small lakes has cut through the sand. This is the only point where anything like a cross-section of one of these ridges could be obtained. The eroding action of the stream has produced a ravine with exceedingly

steep sides composed almost entirely of white sand. The underlying clay now forms the bed of the stream. The width of the ridge varies from a few chains at the south to over half a mile at the north end.

South and west of the lakes along the meridian the timber is second growth, but over the remainder of the area there is a growth of jack-pine, spruce and birch of fair size. To the west of the ridge the soil is clay, timbered with spruce and poplar, some of which reaches a diameter of over 2 feet. The south half of lot 9 in the second concession is mostly muskeg; but for the 3½ miles north of the Abitibi the land is all high, with a good clay soil and mixed timber, with an average diameter of 12 to 16 inches. Along the river bank, which is at this point from 70 to 80 feet high, considerable balm accompanies the poplar and spruce. In what would be lot 9 in the third concession, after the subdivision of the township, there are two outcrops of pyritiferous greenstone, much resembling the rock on the Abitibi at the Two Portages.

Tributaries of the Abitibi

Next to the Black river, the two largest tributaries of the Abitibi enter that river from the north in lot 9 of the sixth concession of Rickard. The larger of these is known as the Misto-ogo river, and has been described by Mr. Coulthard.[4] The other, which enters the Abitibi some 20 or 30 chains below the mouth of the Misto-ogo, has not been previously described. Both have their source in the country north of Galbraith's base line, the Misto-ogo to the northeast of the farthest corner of Wesley, and the other to the northwest of the northwest corner of that township.

The Misto-ogo river crosses the base line a little east of the middle of the 31st mile, and enters the township of Wesley about one mile south of that line with a width of 40 feet. About a mile down from this last point it is joined by a creek 12 or more feet wide, which flows from the west. The river is navigable for canoes as far as this point, that is, to within about 2 miles of the base line, and by dint of much lifting over driftwood, the line itself may be reached. It was crossed, in what would after subdivision be lot 9, at a distance of 2 miles and a quarter from the south of the township. It was here flowing west in a ravine at least 40 feet deep, and had a width of one chain and a depth of 4 feet.

The more westerly creek crosses the same base line near the middle of the 23rd mile, with a width of 15 feet. It flows southeast in a beautiful valley about 10 chains wide and 30 feet deep, and crosses the meridian near the 11-m. post.

A creek 10 feet wide, which crosses the meridian 12 chains south of the 10-m. post, forms a junction with the main stream about half a mile to the east of this line, and from this point to its mouth the course of the stream is nearly south. A traverse of the lower 2¼ miles as far as a log jam indicated that the general course of this part of the stream was a few degrees east of south. The depth of water in the lower part is from 1 to 3 feet; and the width is one chain. Above the log jam there appeared to be a considerable narrowing of the stream. At a distance of half a mile from the mouth there is an outcrop of greenstone on the right bank at the water's edge.

The portion of the Abitibi basin drained by these two streams may be divided into three parts: (1) a river marginal portion in the southwest of Wesley township; (2) a portion which is grown over with second-growth timber reaching diagonally across the township in a northwest direction, and a third portion, consisting largely of spruce woods, in the northeast of the township.

The river marginal portion extends along the west boundary of Wesley from the Abitibi river to the middle of the township. Four miles east of this it extends only one mile into the township, or to a little over 2 miles from the river.

4 Report of Survey and Exploration of Northern Ontario, 1900, p. 45.

The area of second-growth timber reaches to the Abitibi, from the bend in the river at the island portage to a point a short distance east of the township of Wesley. It has here a width of 2 miles, stretching inland to a muskeg in the second mile on the east side of Wesley. It extends with a nearly uniform width across the middle portion of the Misto-ogo valley, and along the two branches of the more western stream beyond the base line. This area was burned over about 35 years ago, and the oldest trees are therefore about 30 years of age. Along the streams the timber growth consists almost entirely of small poplar, usually from 1 to 5 inches in diameter. In a few places, however, trees of 10 inches were seen. The valley mentioned in the northeast corner cf Edwards and the surrounding parts contain only a very few scattered poplar and spruce, and are in their present condition almost ready for the plow. Some of the land along the Misto-ogo is hardly less open. These areas are mostly grass-covered. The other extreme however is reached in those portions removed from the streams. These are quite level, and for the most part grown over with a thicket of small spruce, alder and tamarack, through which it is almost a burrowing operation to pass.

In the upper portion of the Misto-ogo basin, the timber along the streams consists of poplar, spruce and balsam. The largest timber grows along the creek which flows east at a point one mile south of the 28-m. post on the base line, and has already been described. The poplar here averages 18 inches and the spruce 15 inches, and this is at a distance of 6 miles from the Abitibi. But over the greater part of this tract the timber consists almost entirely of spruce from 6 to 10 inches in size.

The soil over the whole of this region is clay, with the exception of a few narrow muskegs within the areas of spruce woods. Good drainage is secured to almost the whole by these two large streams and their branches; while, as has been pointed out, some parts along these streams could be cleared with little difficulty.

Effects of Imperfect Drainage

The greater part of the township of Edwards, and the northeastern part of Aurora, is typical of those areas situated at such a distance from the river that few or no streams have cut ravines through them. A muskeg with a depth of 5 to 6 feet of peat at a distance of half a mile from the edge occupies the greater part of what would be after subdivision, lots 4 and 5 in the second, third and south half of the fourh concessions of the township of Edwards; while another occupies lot 9 in the fifth concession. In these muskegs several streams take their rise, and flow, through flat clay land wooded with spruce, on the one hand east to the large creek in the region just described, and on the other southwest or west to the Abitibi river. One of these flows northwest from the muskeg in the fifth concesssion and crosses the base line in the 19th mile with a width of 8 feet. Two creeks, each 6 feet in width, which flow through spruce woods near the middle of the line between Edwards and Aurora, unite half a mile to the west, to form a creek 10 feet wide, which flows west to the Abitibi in a ravine 20 feet deep. Another of the same width flows south in lot 9 through the first two concessions of Edwards in a ravine, increasing in depth to 30 feet at the town-line of Teefy, and to 60 or more in that township before joining the Abitibi river below Iroquois falls.

Along these creeks some poplar is usually present with the spruce, but over the central portions of the area the timber is mostly spruce averaging from 8 to 10 inches in diameter, accompanied by some balsam on the higher parts, and by dry tamarack where the land is very level.

The soil is clay throughout the area. In the spruce woods it is covered with one to two feet of moss and mould. But in the parts where tamarack is also present, though the land may be quite wet, only a few inches of moss covers the soil. Whether this is a natural condition, or the result of the sun's rays gaining access to the ground since the killing of the tamarack, is not easily determined, but I am inclined to think the latter is the case.

Rock Outcroppings

Several outcrops of greenstone and of green schist occur within this area. A low hill of green schist crosses the base line a quarter of a mile west of the 22-m. post. The rock, which has a strike north and south, and a dip nearly vertical, contains small masses of quartz, which have been pressed out by the shearing action that gave the rock its structure.

Running S. 18° W. from a point nearly 2 miles south of the 19-m. post on the same line, there is a dike of granite 10 feet wide in mica schist or Huronian gniess, with pyritiferous greenstone on either side. This dike was noticed at two points nearly 2 miles apart. At the more northerly point no gneiss was seen, and the dike of granite formed the east side of a ridge of the same greenstone.

At a point 2 miles north of the post on the townline of Teefy for lots 8 and 9, there is a hill about 100 feet high composed of green schist or a schistose greenstone, and at a point 30 chains east of this hill an outcrop of greenstone—probably a diabase.

Teefy, Calvert, Aurora

As a whole the township of Teefy is perhaps the best wooded in the region. Practically the whole township is timbered with poplar with an average diameter of 18 to 20 inches, spruce with an average diameter of 12 to 15 inches, balsam and birch. The soil is good, but somewhat cut up by ravines. A branch of the one previously mentioned in the northeast corner of the township has in lot 8 of the sixth concession a depth of about 60 feet. On the east side of the township, both above and below the Two Portages, there are several others, not however so deep. In the southern part of the township, the timber has suffered considerably from wind storms.

The same is true of the southern part of Calvert, at least along the line between concessions two and three for the first two miles. The third mile is mostly muskeg with 5 feet of peat, and the fourth spruce woods with 8-inch timber.

In the northern part of Calvert the timber is of better quality, and unaffected by windfall. For a distance of 4 miles west from Iroquois falls, the timber consists of poplar, spruce, balsam and birch of about the same size as in Teefy, and the soil is of the best quality of clay. On the east side of lot 3 a ravine nearly 100 feet deep has been cut across the fifth concession by a creek 10 feet in width. On the opposite side of the Abitibi, a creek of equal width has cut a ravine 50 feet deep across the sixth concession. The land along this creek and for a distance nearly 2 miles east is wooded with mixed timber of smaller size than on either side of the river at Iroquois falls. Along the line between concessions five and six, the first mile only to the west is good land, the sand area being reached at this point.

On the west side of the deep ravine where it crosses the line between concessions four and five a rock consisting mostly of hornblende, forms an almost perpendicular wall. Along the same line north of the post for lots 8 and 9 there is a ridge of pyritiferous greentsone; and at the post one mile north of this is a hill of greenstone about 150 feet high. About the edges of this hill the greenstone is distinctly schistose.

The central portion of the township of Aurora is distinctly lower than the districts which have just been described, the ravines having here a depth of only about 20 feet. East of the Abitibi in the second concession, the marginal timber extends only to a distance of one mile from the river, and even in this mile spruce predominates. Two miles of 10-inch spruce succeed this to the east. West of the river along the line between concessions one and two, there is mixed timber with spruce predominating, for a distance of 2 miles, to a large muskeg in the 8th mile on the meridian line. This muskeg extends across the concession line with a width of 30 chains, while another occupies the first half mile north of the corner post of the township.

The country 2 miles west of these muskegs may be described as wet clay land, with tamarack windfall and alder. The timber is of little value, it having been an area of tamarack, which is now all dead.

East of the small rapid two miles above Buck Deer rapids, there is only half a mile of marginal timber. Spruce, of an average diameter of 8 to 10 inches, is the principal timber as far as the ridge of greenstone in Edwards, where there is some stony land wooded with birch, balsam and other timber. North and east of Buck Deer rapids the country is higher, and is wooded wih large poplar, balm and spruce for a distance of 2 miles. In the 16th mile along the base line the timber is of the same kind, but of smaller size, the spruce averaging from 6 to 8 inches. The 17th mile is mostly muskeg, a sounding showing a depth of 4 feet of peat.

Buck Deer Rapids Area

Lastly, the country west and southwest of Buck Deer rapids will be described. This land is drained by a creek, which crosses the meridian line with a width of 12 feet, at a point 20 chains north of the 11-m. post, and enters the Abitibi about half way between the rapids and the base line. This creek takes its rise in the southwest corner of Newmarket, and flows diagonally acress the township. Where it was crossed, at a point 2 miles east and half a mile north of this corner of the township, it had a width of 5 feet, and a bank 10 feet in height. The country for a mile south and for half a mile north was wooded with 12-inch spruce, poplar and balsam, and had a good clay soil. This was followed to the north by half a mile of spruce, when the large muskeg—over two miles across at this point—was reached. A lake nearly 60 chains long and one-third as wide lies near the south east end of this muskeg, and it is probable that a stream flows east from this lake to join the creek last mentioned. A sounding made in this muskeg showed a depth of peat of 11 feet, which is the greatest in the region.

For a distance of one mile west of this creek, in the second and third mile south of the base line, the timber is large, some of the spruce measuring 26 inches in diameter. It consists of red and white spruce averaging 12 inches, balsam, birch and poplar. The area of second-growth in the northeast corner of Mann extends over two miles east into Newmarket in the second mile south of the base line. The first mile north of the muskeg, and the middle of the township at a distance of one mile from the base line is timbered with 8-inch spruce. To the east of the tract of large timber along the lower part of the creek is an area of excellent farming land covered with second-growth. In the 11th mile on the meridian, the poplar has grown to a size of 12 inches, and the spruce to one of 8 inches; but over most of the area it is too small to be of value; consisting of 6 to 8 inch poplar and balm and brushy spruce of smaller size.

The soil over this area is a clay of good quality, and in all the northern part is sufficiently dry to be well adapted for farming. In the beds of the streams pebbles of greenstone, granite and shale were noted; and in a deep ravine at the northeast corner of Newmarket some interesting concretions composed of clay were seen. At a point 2 miles east and the same distance south of the northwest corner of Newmarket there is an outcrop of granite, the only rock seen in the area.

Rock Outcrops on the Abitibi

The rock outcrops on the Abitibi river have mostly been described in previous reports: those below the Two Portages by W. A. Parks,[5] and W. J. Wilson;[6] and those between the Two Portages and Abitibi lake by Wilson, Baker and Coulthard.[7]

[5] Eighth Rep. Bur. Mines, p. 181. [6] Geol. Sur. Can. Sum. Rep., 1901.

[7] Report of Survey and Exploration of Northern Ontario, pp. 29 and 46.

Little will be said about the outcrops described except to define their location more accurately. On an island at the foot of Buck Deer rapids there is an outcrop of greenstone—probably a dike—with glacial striæ S. 5° W. The rock at Buck Deer rapids has been described by Dr. Parks as hornblende gneiss, and that at a constriction in the river near the middle of the township as gneissoid granite.

About half a mile below this last outcrop, a red biotite granite was noted near the water's edge on the left bank. Another outcrop of granite occurs on the right bank about the middle of the first concession of Aurora.

About the corner of lots 2 and 3 in concessions five and six of Calvert, which comes in the river, there are several outcrops of granite and gneiss reported upon by Mr. Wilson.

Three-quarters of a mile above on the right bank there occurs a very hard silicious green rock, with smoothly glaciated surfaces, containing a dike of granite about a foot in width, with stringers of the same running into the darker rock. The eruptive contact of the Laurentian occurs between these two points, but could not be more accurately located.

The next outcrop above occurs on a small island near the right bank on the east town-line of Calvert, and consists of schistose greenstone.

On the same bank, just above the line between concessions four and five of Teefy, there is a dike of felsite 9 feet wide running north and south, and a 3-inch vein of glassy quartz in massive greenstone.

Between Iroquois falls and the Two Portages, in addition to the green schist where the river first crosses the south town-line of Teefy, which has been noted, there are two outcrops, one on the right bank in the south part of the third concession consisting of similar rock, and the second of quartzite with glacial striæ S 20° E. on the same bank half a mile below the lower of the two portages.

Above the barrier of weathered pyritiferous diabase at the Two Portages, there are at least three outcrops of massive greenstone, the last a short distance above, and the middle one at a small rapid in the fifth concession of Teefy.

At the next rapid a short distance above the meridian line, the greenstone is distinctly schistose.

At the 7-chain portage on the left bank at the crooked rapid, a weathered greenstone was examined, and a short distance up stream a similar rock was seen on the same bank.

On the island portage—8 chains in length—at the next rapid, green schist and a bluish gray silicious schist containing veinlets of quartz occur.

About lot 8 in the township of Knox, there is an outcrop of greenstone on the north bank of the river, and half a mile east another, somewhat schistose in structure.

On the south bank in lot 5 two bluffs of greenstone about 15 chains apart occur.

The rock at the rapid about half a mile below the meridian line is a much-weathered quartz porphyry, gray in color.

At Couchiching falls, and at a point on the north bank half a mile below, the rock consists of a hard fine-grained greenstone.

No outcrops occur above the falls until within half a mile of the lake, where there is a dark-colored hornblende-biotite granite on the north bank. This is probably a dike striking N. 30° W., as it is badly weathered along planes in that direction.

III. RESOURCES OF THE REGION

The Soil

The principal asset of the region is its soil, samples of which have been taken by Mr. Henderson, and will be dealt with in his report. As has been pointed out, the soil over almost the entire area is clay of good quality. The sand areas are so small as to be a benefit, rather than a detriment, to the region, considered as a whole.

The district is at present rather subject to summer frosts. Two occurred this year, one on 23 July, when the temperature recorded was 26° F., and the other on 31 August, when it was 27° F. These seem to have been unusually severe, as no frosts were reported by Mr. Kay between 17 June and 1 September last year. The large amount of moss-covered land which retains the frost until late in the summer is no doubt largely responsible for these frosts, and the clearing of the land, which would admit the sun's rays and result in the killing of the moss, would raise the average temperature several degrees, and make these frosts very rare or do away with them entirely.

On account of its distance from the railway—150 miles in a straight line, or 200 by canoe—this region has been generally considered a more northern one than it really is. The highest latitude reached this year is just about the 49th parallel, so that the whole of the region lies to the south of the most southern point of Manitoba.

The areas best adapted for settlement are, the Abitibi basin, for an average distance of 3 miles on either side of that river, the basin of the Frederick House, for a width of 2 miles on either side of the river, the basin of the Mattagami river, for a rather less width, and the parts adjoining the main tributaries of these rivers at greater distances from them than those mentioned.

The drainage of these areas is secured by the numerous ravines, which have been eroded to distances of 2 or 3 miles from the river. It is probable that the clearing of the land, alone, will add considerably to these areas.

The streams are young, as shown by their V-shaped valleys; and, as in other parts the removal of the forests will lead to a cutting back of these ravines to much greater distances than they have reached at present. The areas farthest removed from the rivers, such as the spruce land in Prosser and Tully and in the southern part of Wark and Gowan, parts of the next four townships to the north of these, portions of Newmarket and McCart, the township of Edwards, and the township of Moody will require artificial drainage. None of these areas however are more than 4 to 6 miles distant from streams, with valleys of considerable depth, and with anything like the efforts that have been made to drain many parts of older Ontario, even the muskegs would be turned into arable land.

Building Materials

The timber available for lumber consists of spruce, poplar and balm. The spruce only is suited for lumber for outside use. Poplar and balm could be used where not exposed to the weather. The jack-pine growing on the sand areas is of a size suitable for making railway ties. The dry tamarack standing in many parts will also provide suitable tie timber.

The only stone available, besides loose material of this kind, which is not plentiful, is the eruptive greenstone forming the isolated hills in the region. Gravel for concrete masonry and sand for mortar could conveniently be obtained in almost every part of the region, from the glacial ridges. Sand of good quality is to be found in the fourth mile on the line between Teefy and Rickard. Ballast for railways is to be found in the same ridge, in the sand area in Calvert township, and at the north and south ends of the ridge west of the Frederick House river. Clay for brick-making is plentiful in every part of the region. That along the Frederick House in the township of Little was found to bake readily.

Timber

The only red or white pine, other than the small area near the outlet of Abitibi lake, is a small clump at the falls on the Frederick House and a few scattered trees on some of the ridges. There is no timber for export as lumber. The local require-

ments will consume all the spruce or other timber large enough for manufacture into lumber. But in the large areas of spruce, the country possesses resources which can be marketed as pulp, once mills are established on the rivers. The facilities for driving the pulpwood are fair. The difficulty lies in the driftwood which blocks all but the largest tributaries at a short distance from their outlets into the main rivers. Most of this could be cut out or drawn out; but some of the jams on the larger streams would require the use of dynamite.

Water Powers

The most easily developed water-power in the region is situated on the Frederick House river in the township of Mann about a quarter of a mile from the south town-line. These cascades have, according to Dr. Parks, a fall of 46 feet. The rocky barrier which rises only a few feet higher than the level of the water above the falls, has a width of a little over 200 feet. An excavation of this length on the right bank will make available the full height of the falls.

In the fifth concession of the same township on the same river, two chutes 5½ feet and 2 feet in height, respectively, and only a few chains apart are separated by 5 chains of smooth water from a rapid 30 chains in length, with a fall, as given by Parks, of 14½ feet. This provides, in a distance of about half a mile, a total fall of 22 feet. This drop might be taken advantage of for power purposes, by building a dam about 100 feet in length across the river near the foot of the rapid.

On the Abitibi river three water-powers are available within the region explored. The largest of these is at Couchiching falls, where the river drops about 30 feet in two successive cascades over a barrier of hard greenstone. These cascades are followed by about a quarter of a mile of very rough rapid. The total fall is given by Wilson as 46 feet, and by Baker as 45 feet (by aneroid). In order to take advantage of the total drop, a great deal of excavating would be necessary, and even to utilize the main drop for power purposes would require an excavation between 300 and 400 feet in length, unless the power house was built over the lower of the two cascades. A central mass of rock which divides the stream laterally would materially aid in this.

At the Two Portages on the Abitibi a second water power could be secured. The lower portage is past a cascade with a drop of about 9 feet; while the upper, 100 yards distant, is past a rough rapid with a fall of about 6 feet. Advantage could be taken of the lower fall for power purposes, by building the power house over either of the two main gaps or over a small western gap; but to secure the total fall of 15 feet, a dam about 150 feet in length would have to be built at the lower fall.

At Iroquois falls in the fourth concession of Teefy township, there is another water power which could be easily developed. At this point there is a vertical drop of 15 feet, while in the first two chains from the brink there is an additional drop of about 2 feet. The stream is divided above the falls into three parts by two islands. The western and central streams take the greater portion of the volume of water. By building a coffer-dam to shut off the water from either of these channels, turbines could readily be put in place at the brink of the fall and power secured.

In view of the fact that the country contains so much spruce and poplar suited for pulp making, these water powers are of prime importance. Even with the building of the additional 100 miles of the Temiskaming and Northern Ontario railway necessary to tap the southern part of this region, it is a question if this spruce could be profitably shipped out as pulp-wood in competition with the spruce of the Blanche valley 100 miles to the south; but with the building of mills at some of these points where power can be secured, the expenses of any long freight haul would be eliminated.

As the measuring instruments at our disposal for determining the area of a cross-section of these streams were rather crude, and as surveyors engaged in the neighborhood of Iroquois falls and the first falls on the Frederick House spoke of

estimating the water power at these points, it was not thought advisable to make sections and obtain approximate results as to the energy capable of development. The volume of water in the Abitibi above Couchiching falls has been estimated by W. J. Wilson of the Dominion Geological Survey, who made a section at this point, as 306,000 cubic feet per minute. On this basis the horse-power available at these falls is about 16,000, without taking into consideration the rapids below the main fall. The power available at Iroquois falls, and at the first falls on the Frederick House would be in each case at least half of the above.

Muskegs or Peat Bogs

It is possible that, with the advances which are being made in the manufacture of peat-making machinery, these may prove a valuable source of fuel, but it will likely be in the country still farther north where they are more extensive, that peat manufacture will be carried on to the greatest extent. The largest of these, in the townships of Wark and Gowan, has an average width of a mile and a quarter, and a length of about twelve miles. This represents an area of nearly 10,000 acres, with an average depth of peat of 6 or 6½ feet.

The second largest, in the township of Newmarket, has an area of about 2,500 acres, the greatest depth of peat being 11 feet. The muskegs in the townships of Edwards and Moody are about the same size and have together an area of 2,500 acres. This makes a total area of 15,000 acres or about 1½ per cent. of the area of the region. Adding another 1½ per cent. for the areas of smaller muskegs, the total area of muskeg within the region may be put down as three per cent. of the whole.

Below will be found analyses of some samples of peat, made by Mr. A. G. Burrows, Provincial Assayer, Belleville.

Locality and depth.	Water.	Volatile Combustible.	Fixed Carbon.	Ash.	Remarks.
	Per cent.	Per cent.	Per cent.	Per cent.	
29 m. post Patten's Meridian, 2 ft. down......	11.28	57.36	23.08	8.28	Yellowish green ash
North of Abitibi River from mouth of Dokis River, 2 ft. down..........	8.72	65.52	21.04	4.72	Yellowish ash
2 m. 50 c. north of 4 m. post Patten's first base line, 1 ft. down..........	9.42	66.96	18.14	5.52	Yellowish ash

A sample of marl from the bottom of a small lake north of the northern arm of the Montreal river on the canoe route to Night Hawk lake, analysed by Mr. Burrows contained:

	Per cent.
Insoluble residue	11.14
Lime	36.36
Magnesia	.60

A specimen of pyrites from the west bank of the Montreal river two miles below Fort Matachewan, was found by the writer to assay $1.50 per ton in silver.

IV. PETROGRAPHY

The greater part of the region has been mapped as Huronian. In this part basic eruptives are the most commonly occurring rocks. Almost all stages of alteration of these rocks are to be seen. Some are sufficienty fresh to be classed as gabbros, diorites, and diabases; others which have been classed as schistose greenstones and green schists, though considerably metamorphosed, show undoubted igneous origin, while in others the metamorphism has been so great that no trace of the original rock remains, and they can only be classed according to their principal constituent, as chlorite, sericite, or other schists.

No rocks of sedimentary origin were encountered. A rock outcropping on the right bank of the Abitibi below the Two portages, which in the field was thought to be a quartzite, appears when examined microscopically to be a much altered ash rock, containing a great deal of leucoxene and some feldspars.

Quartz porphyries outcrop at the Sandy Portages on the Mattagami, and at the first rapid below Couchiching falls on the Abitibi. The only other acid rocks are a syenite near the junction of the two main creeks east of Patten's meridian, and a similar rock reported by surveyors about the sixteenth mile on that line.

In the V-shaped Laurentian area, the apex of which reaches to within a mile and an half of Iroquois falls, the rocks are mostly gneisses and granites with a few mica schists and greenstones.

The contact has been located by Dr. Parks on the Frederick House river at Neelands rapids, and at the point mentioned on the Abitibi by Wilson. At no point has a clearly defined line of contact of the two rocks been established. A dike of granite 1 foot wide in altered greenstone, on the right bank of the Abitibi between lots 1 and 2 in the fifth concession of Calvert township, must be very near the line of contact. To the northeast of this point the contact has been placed near the 10-foot dike of granite in greenstone which crosses lots 10 and 11 in the fourth concession of Edwards, with a direction N. 10° E. To the northwest of the apex the line of contact has been plotted, cutting off the southwest corner of Aurora and passing south of the granite outcrops in Newmarket and in the middle of lot 2 on the north boundary of Mann, in a fairly straight line to Neelands rapids on the Frederick House. To the west of this river no outcrops were seen; and as a consequence, it it could not be determined whether or not the line of contact continues to the westward as plotted on previous maps. Another V-shaped projection may be represented by the syenite mentioned above.

Gabbros

From the microscopic study of a number of thin sections, these seem to be the most commonly occurring basic eruptives. A specimen from the right bank of the Abitibi half a mile below the outlet of Abitibi lake, consists principally of augite, hornblende, plagioclase and orthoclase. From the angle of extinction, the plagioclase feldspar is seemingly andesine in part at least. Quartz crystals are present in small amount. Biotite occurs as a secondary constituent; while crystals of apatite and magnetite are present as accessory constituents. The micro-structure is distinctly idiomorphic.

The gabbro from near the mouth of the large creek which joins the Frederick House 1½ miles above the point where it crosses the district line, was found to consist of augite, plagioclase feldspar, and secondary chlorite.

A greatly weathered specimen from lot 5 in the third concession of Tully consists largely of decomposition products, chlorite, serpentine, kaolin and calcite being all present. Remains of the augite crystals are however plainly to be seen, and small but well-formed crystals of plagioclase with an angle of extinction corresponding to bytownite. Pyrite is present as an accessory constituent.

Diabases

The best preserved specimen is from near the middle of the 42nd mile on Galbraith's base line. It is idiomorphic in structure and consists of augite slightly weathered to hornblende, plagioclase with an angle of extinction of about 20°, and biotite in small amount. Considerable magnetite is also present in this rock. Specimens from the Two Portages and elsewhere were found to be much altered by weathering.

Peridotites and Picrites

The serpentine rock which outcrops on lot 9 in the third concession of Mann, and on the Frederick House river at the Three Portages, is most interesting in thin section. Besides the serpentine which is the chief constituent, considerable magnetite, and some orthoclase are also present. Under crossed nicols the shape of olivine crystals with characteristic net structure due to weathering can be distinctly seen, but the olivine has been almost enirely weathered to serpentine. This points to the rock being an altered peridotite.

A schistose greenstone from lot 8 in the third concession of Prosser consists largely of serpentine aggregates, and chlorite, with pyrite in subordinate amount. Remains of crytsals of olivine and augite imply that this rock is a greatly weathered picrite.

Diorites

A greenstone from the west side of lot 2 in the second concession of Mann was found to consist of hornblende, biotite, plagioclase, quartz and magnetite. Hornblende, which is the chief constituent, is present in large crystals, and also in small needle-shaped crystals within the quartz. The rock is best described as a quartz diorite.

Diorite porphyrites, which have been described by Dr. Parks, outcrop along the Frederick House river, near the north and south town-lines of Mann. These rocks contain large crystalline aggregates of plagioclase feldspar in a diorite ground-mass.

A greenstone outcropping 2½ miles east of 14 m. 30 c. on Patten's meridian may best be described as an altered diorite. Chlorite and serpentine are both present in considerable quantity, the first distinguishable by its dull polarization colors and parallel extinction. A mineral with high double refraction appears to be epidote, formed from decaying feldspars. A completely weathered white mineral gives the rock a poikilitic structure.

Schists

The schists, which include hornblende, chlorite, sericite and quartzose schists, are found in the southern part of the district.

Most of the green schists consist principally of hornblende and chlorite and contain pyrite, magnetite, or even hematite as accessory constituents. The best example of chlorite schist is from the shore of Abitibi lake, about one mile east of the end of Galbraith's base line. The only sericite schist examined outcrops on a small island near by.

A light-colored rock which outcrops in association with green schist below the Two Portages, though resembling a quartzite, appear under the microscope, as a much altered ash rock. It consists largely of leucoxene with small quantities of feldspars, chlorite and possibly quartz.

Schists containing considerable quartz outcrops in the southern parts of Little and Prosser. These are greatly stained by limonite.

The garnetiferous biotite schist at Neelands rapids was the only sample examined from the Laurentian portion of the region.

Porphyries

Two quartz porphyries were noted, one outcropping as a dike at the first rapids below Couchiching falls on the Abitibi, and the other at the upper rapids at the Sandy portages on the Mattagami. The first contains phenocrysts of quartz in a badly weathered ground-mass. The second is porphyritic in structure when examined in thin section, with an unusually large proportion of the constituents crystallized out from a devitrified ground-mass. Crystals of quartz and orthoclase are distinctly

seen under the microscope, and others which appear to be of plagioclase with an angle of extinction of about 15°. The fine-grained nature of this rock causes it to resemble a quartzite in the field.

Granites and Gneisses

These rocks of the Laurentian portion of the region are the only ones of an acid nature besides the few quartz porphyries and syenites which occur as dikes in the Huronian. The gneisses, which are indistinctly banded and similar in composition to the granites, might be described as gneissoid phases of these rocks. The granites include hornblende and biotite varieties. The scarcity of outcrops, excepting along a short portion of the Abitibi, made it difficult to secure fresh specimens.

One of the best preserved specimens from the bank of the Abitibi near the post for lots 2 and 3, concessions V and VI of Calvert, is composed of orthoclase, quartz, hornblende, and plagioclase, and is distinctly porphyritic in structure. The hornblende, which is composed in part of twinned crystals, can be seen changing to biotite. Secondary kaolin has also been formed from the decay of the orthoclase, and apatite crystals are present as an accessory constituent.

In closing, I wish to thank Dr. Coleman and Dr. Walker of the University of Toronto, for assistance in the study of the rocks described.

AGRICULTURAL RESOURCES OF ABITIBI

BY ARCHIBALD HENDERSON

In May, 1904, Mr. T. W. Gibson, Director of the Bureau of Mines, instructed the writer to accompany, in the capacity of agriculturist, Mr. J. G. McMillan, B.A. Sc., in an exploratory survey of that part of the northern clay belt lying between lake Abitibi and the Mattagami river.

We set out in two canoes on the west branch of the Spanish river at Matagama siding, on the Canadian Pacific railway, in the early morning of June 1, and seven days later the scene of our explorations was reached. Work began on June 9 in the country between Murphy township and the Mattagami river. The last camp from which overland trips were made was on the Frederick House river about four miles below milepost 157 on Niven's line. The homeward paddle started from here on September 24, the Temiskaming and Northen Ontario railway being reached at the point where it intersects the Montreal river on Monday morning, October 2. Thus four months were spent in the north country.

THE TERRITORY EXPLORED

The district with which this report is concerned is roughly one thousand square miles in extent, *i. e.*, about twenty-eight townships. It includes the townships of Wark, Gowan, Prosser, Tully, Little, Mann, McCart, Newmarket, Calvert, Aurora, Teefy, Edwards, Rickard, Wesley, Knox and Moody; the unsurveyed area between the eastern boundaries of Knox and Moody and lake Abitibi, which is approximately equivalent to two townships; the unsurveyed area between Murphy and the Mattagami river, roughly one township and a half; an unsurveyed area northwest of Prosser, one-half a township; six townships north of Prosser and Tully; and two townships north of Mann.

This country was explored by overland trips, two or three miles apart. Notes were made at the end of each mile, recording in chains the length of each of the various types of surface as I shall describe them. Here and there samples of soil for future chemical and physical analysis were taken. I am enabled thus to present a report on the whole district and on each township, stating in both cases an estimate of the proportional area of each of the various types of country.

The report of the work accomplished is presented under the following headings:

I. Soil and Timber.

(a) General Description.
(b) Description of Townships.

II. Climate.

III. Flora.

IV. Fauna.

V. Conclusions.

VI. Appendix.

(1) Results of Chemical Analysis of soil samples by Prof. Harcourt.
(2) Results of Physical Analysis of soil samples by Prof. Reynolds.

I. SOIL AND TIMBER

(a) General Description

For the sake of avoiding repetition, and also for the benefit of those who wish only a general idea of the soil and timber of this region, I shall describe the types of area of which it is composed, and refer to their relative proportions. Afterwards, I shall describe individually the townships explored, giving the percentage of the various types present in each, and other details.

The types of country are as follows: (1) Black Spruce Forest; (2) River Bank; (3) Poplar Knoll; (4) Muskeg; (5) Jack-Pine Plain; (6) Rock.

(1) BLACK SPRUCE FOREST

Over half—about 59 per cent.—of that part of the Clay Belt explored is covered by a Black Spruce forest. The subsoil is mostly wet clay and clay loam overlying which are from one to four feet of rich black mould, which, when mixed with the clay by cultivation, will make a good soil for farming purposes. Above this again, are from six to twelve inches of moss, mostly a species of sphagnum. Many areas are drier in nature, waterpools being infrequent, and the surface not so flat as is usually the case. The soil in these is often of a lighter nature, being a sand loam in some cases. It is covered by only a few inches of decaying organic matter, on which many bryineous mosses thrive.

As the name of this type of area indicates, the predominant forest tree is the black spruce (*Picea nigra.*) This tree varies very much in size, attaining a diameter in some areas of fifteen inches, but averaging from eight to ten, and having clean boles from forty to seventy-five feet in height. Its growth is a slow one, the eight-inch tree often being about one hundred years old.

The next most prominent tree is the tamarack (*Larix Americana*). This tree is thinly scattered throughout the spruce woods, but in some of the very wet localities it becomes the predominant timber constituting the so-called tamarack swamps. Unfortunately, the tamaracks of this region are now all dead, having been killed within the last few years by the larch saw-fly. In the tamarack swamps there is a dense undergrowth of hoary alder (*Alnus incana*), which makes "travelling" in these localities exceedingly difficult. Many of the tamarack, ten to fifteen inches in diameter, are as yet perfectly sound and would make good railway ties, for which purpose such timber has been utilized in the Temiskaming country.

The balsam (*Abies balsamea*) is also found almost everywhere throughout the spruce forest. The trees, however, are usually small, both in diameter and height, and are of little commercial value. Moreover, the wood is very soft, and they are therefore readily broken down by winds, and are thus, more than any other kind of tree, responsible for the great number of fallen trees characteristic of the region.

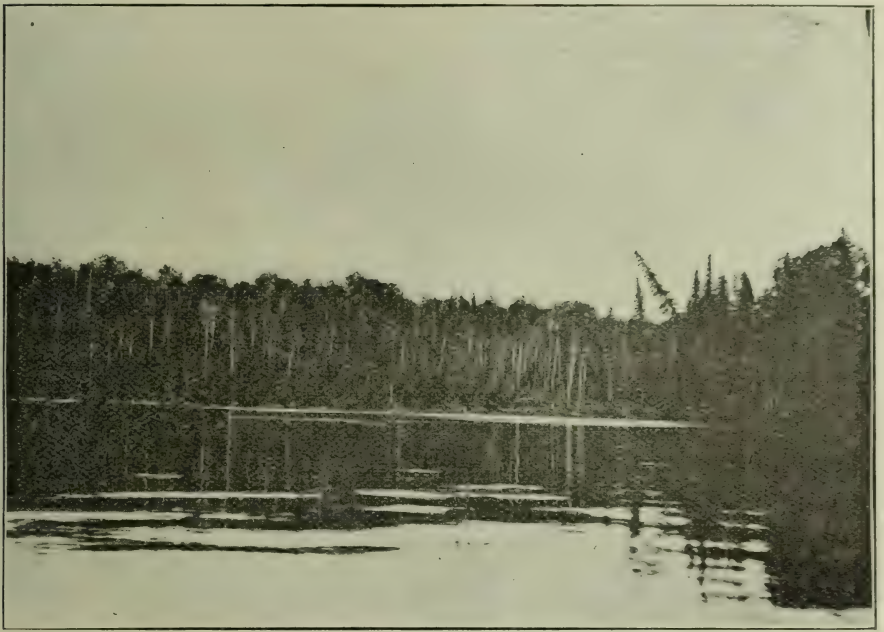
White birch (*Betula papyrifera*), not often over twelve inches in diameter, is sometimes found in the drier parts of the spruce forest. As has been said, the soil in such localities is often of a lighter nature than elsewhere. White spruce (*Picea alba*), too, often grows in these areas.

(2) RIVER BANK

In the region covered by this report there are three large rivers, the Mattagami, the Frederick House, and the Abitibi. Besides these rivers there are numerous tributary streams, and along either side of all, there is a strip of country varying

in width from a few chains to two miles, which differs very much from the spruce forest. It has been called the River Bank type. A similar area around small inland lakes in also included in this type.

The soil is, as a rule, a clay loam or a loam with a good amount of humus, and, as the luxuriant natural vegetation shows, as well as the chemical and physical analyses, is admirably adapted to the purposes of the agriculturist.



Typical river bank scene. Mouth of Black river.

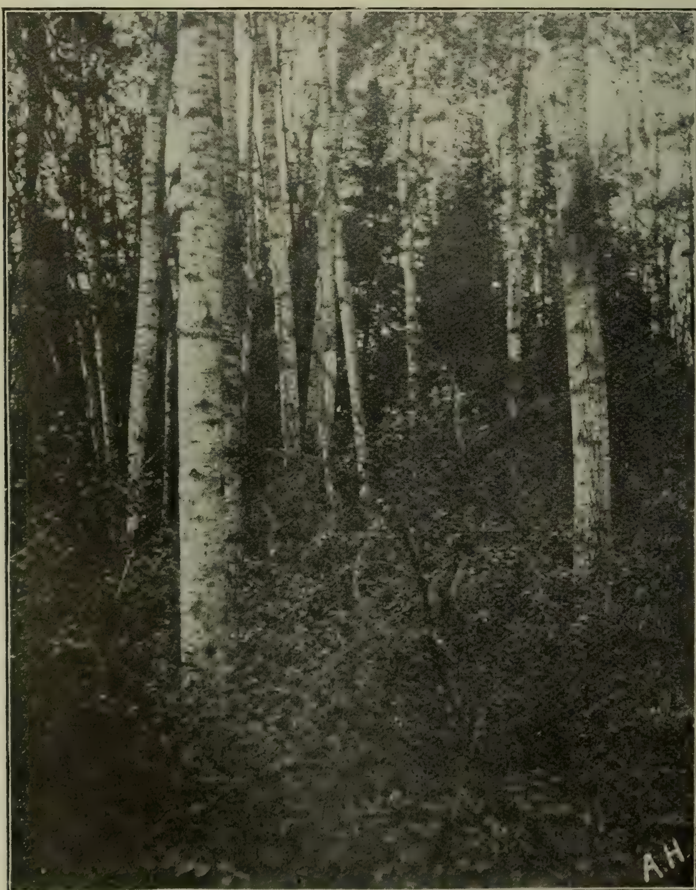
The most apparent difference, however, between the black spruce forest and the river bank types, is in the forest growth. The predominant tree in the latter is the aspen poplar (*Populus tremuloides*), which sometimes attains a diameter of thirty inches, averaging about fifteen. Many of the very large trees are rotten in the center, having attained their maximum size and begun to decay. The aspen has been very useful to the settlers of Manitoba and the North-west Territories for building purposes, and is still much used there as firewood. The aspen of the Clay Belt, however, is a very much larger tree than that of the West.

The next most common tree is the balsam, which averages about eight inches in diameter. As stated above it is of little value.

The white spruce, the most valuable timber tree of the Clay Belt, grows along the river banks. It frequently attains a size of twenty-eight inches in diameter, averaging about sixteen. One tree, which grew on the bank of a creek in Tully township, and which was cut down by the surveyor, measured thirty-two inches across the stump. This tree had only one hundred and twent-eight annual rings, thus indicating a rapid growth when compared with that of the ordinary tree of the black spruce forest. The white spruce is also sometimes found inland growing with black spruce, white birch, and aspen.

A growth of white cedar (*Thuja occidentalis*), is usually present along the margins of the rivers. This, for the most part, is commercially valueless; but around the shores of small inland lakes there is sometimes a growth of short thick cedar, many trees even twenty inches in diameter and not more than twenty-five feet high.

Wherever the river bank is sandy or rocky the white birch grows; but it does not often attain a great size, averaging ten to twelve inches in diameter. A few jack pine (*Pinus Banksiana*) are occasionally associated with the white birch and other trees in such localities.



Young poplar knoll. Knox Township.

Growing with the aspen almost everywhere, but much less abundant, is its close relative, the balsam poplar or balm of Gilead (*Populus balsamifera*). This tree in of small plants. These have aided greatly in enriching the soil, and in this way are of more value than commonly thought.

Besides the forest trees there is on the river bank soil, a very luxuriant growth of small plants. These have aided greatly in enriching the soil, and in this way are of more value than commonly thought.

Large poplars, 22 and 24 inches in diameter.

Finally, it should be mentioned that the surface of the river bank country in many localities, is rendered very uneven by numerous short ravines, sometimes having steep banks.

(3) POPLAR KNOLL

Here and there throughout the spruce forest is a slightly elevated area resembling the river bank type, both in soil and vegetation. Like the latter these areas are well drained, and in this respect differ from the black spruce forest.

Calculated together the river bank and poplar knoll types occupy about twenty-five per cent. of the whole region.

(4) MUSKEG

The muskegs of this region vary in size from a few acres to several square miles. In the exreme condition they are treeless tracts of deep sphagnum moss, with often a marshy pond in the centre. Around such an open muskeg the vegetation shades off gradually into the spruce forest, the moss decreasing in depth as the spruce trees increase in size. Thus there are large areas around the open muskegs with a sparse growth of stunted black spruce and tamarack, two to four inches in thickness and twelve to twenty feet in height These muskeg trees, although so small, are the oldest trees in the country, one spruce only three and a half inches in diameter being one hundred and ninety years old.

The sphagnum swamps are usually a considerable distance inland, and from the fact that small creeks were often observed to have their origins here, it would seem

that many of them can be drained, cleared, and the underlying soil used for farming purposes, as has proved true of similar areas in southern Ontario.

Typical muskeg scene.

The peat of the muskegs is sometimes over eleven feet thick, usually resting on a clay bottom. They occupy about thirteen per cent. of the whole region traversed, and in a country lacking coal will doubtless afford a valuable supply of fuel in the days to come.

(5) JACK-PINE PLAIN

As its name signifies the jack-pine plain is a level area covered with a growth of jack-pine (*Pinus Banksiana*). These trees are sometimes sixteen inches in diameter, but average about twelve. Their timber contains much resin and makes good ties. Besides jack-pine a typical desert vegetation is present,—heaths, reindeer moss, bracken fern, lycopods, sweet gale, etc. The soil is sometimes a very fine white sand, though often coarser and suitable for building purposes. As the chemical analysis shows it is of no value agriculturally.

This type of area occupies about three per cent. of the whole region traversed, and is most often found on the divides between adjacent river systems.

(6) ROCK

Occasionally small outcrops of rock, mostly of Huronian age, occur. Usually the outcrops are sparsely wooded with small black spruce. Often around an outcrop is a sandy or bouldery area on which there is a growth of white birch, white spruce, jack-pine, and sometimes a few small poplars. Rock forms less than one per cent. of the district.

SUMMARY

The region traversed, approximately one thousand square miles in area, is made up as follows:—

	Per cent.
Black spruce forest	59
River bank and poplar knoll	24.5
Muskeg	13
Jack-pine plain	3
Rock	.5
Total	100

Jack pine plain, Mattagami. Porcupine portages.

These figures have been calculated from those which are given in the description of the townships. The method of estimating the percentages of the various types of area in each township is explained in the description of the first one.

(b) Description of Townships

MURPHY TOWNSHIP TO MATTAGAMI RIVER

Four overland trips were made through this unsurveyed region, as follows:

(1) Up the western boundary of Murphy on Speight's meridian from M. VII, 50 chains to M. XII. This line was reached by ascending a creek which empties into the Mattagami near the northwest corner of Tisdale township.

(2) West from the northwest corner of Murphy to the Mattagami, eight miles and fifty chains (8 m. 50 c.)

(3) West from the western boundary of Murphy township, three miles south of the second trip, to the Mattagami river, seven miles and seventy chains (7 m. 70 c.)

(4) South, thirty degrees east, from a point on the Mattagami where it was reached on the third trip to another point on this river in that part of its course which forms the southern boundary of this area, five miles and forty chains (5 m. 40 c.)

These four trips total 26 m. 30 c., and according to my chainage notes, this distance is apportioned among the various types previously described as the following table of distances and corresponding percentages shows. The last column gives in inches the average diameter of the trees.

Type.	Mileage.	Per cent.	Trees.
Black spruce forest	18 m. 5 c.	68	7
River bank and poplar knoll	3 m. 55 c.	14	10-12
Muskeg	4 m. 50 c.	18	....
Total	26 m. 30 c.	100	....

These percentages approximately represent the proportions of the various types of country present in the region under consideration. Thus it may be said that sixty-eight per cent. of the region is black spruce forest; fourteen per cent. is river bank and poplar knoll; and eighteen per cent is muskeg. (In the descriptions of the remaining townships the percentages will be given without reference to the distances from which the percentages were calculated. It is sufficient to state that this distance averaged twenty miles and fifty-eight chains per township).

Included in the sixty-eight per cent. of black spruce forest is a considerable amount of tamarack swamp. If calculated alone it would form about four per cent. of the area. This is more than is usually present.

The strip of river bank country along the western boundary of this area is about thirty chains wide, and has a descent to the river of sixty feet in ten chains. It is well wooded with the usual river bank trees—poplar, spruce, balm of Gilead, birch, balsam and some fair cedar. The banks of the Mattagami along the part of its course which forms the southern boundary of this region are very similar.

WARK TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	56	6-7
Poplar knoll	14	10
Muskeg	30	....

On the southern boundary of Wark in the first mile from the western end, there is a deposit of gravel. This, in an almost uniformly clay country will be valuable. A small outcrop of rock also occurs on this boundary.

GOWAN TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	53	5
Poplar knoll	18	10
Muskeg	29	....

One of the largest muskegs seen during the summer occurs in this township. It extends from the northern boundary at a point two miles from its eastern extremity for three miles in a southerly direction, and at least two miles from east to west. Indeed, it is probably a continuation of the muskeg that was crossed in Wark at this latitude.

The Porcupine river touches upon the southern boundary of Gowan, and a western branch of this river drains a portion of the township. The banks of these streams are ten to twenty-five feet high, and are of the usual type, being well wooded with poplar, some twenty inches in diameter, averaging, however, thirteen; white spruce, many sixteen to twenty-two inches; balsam, black spruce and balsam poplar. This river flows through Hoyle, the township south of Gowan, and throughout its whole course its banks are of this nature.

Wark and Gowan are very flat townships, and are poorly drained. This fact is indicated in the table by the large per cent. of muskeg, and the small amount of poplar knoll.

PROSSER TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	74	7 (brulé excepted).
Poplar knoll	9	12
Muskeg	16	.....
Rock	1	.....

A brulé wooded with small spruce, tamarack, willow, balsam and birch about thirty years old, extends along the northern boundary of Prosser township. It begins 1 m. 33 c. from the eastern boundary and reaches a point 1 m. 65 c. from the western. It also stretches south 50 c. into Prosser, and about 2 m. into the township north of Prosser. Flowing in a northwesterly direction through this brulé is a stream twenty-five feet wide, which crosses the northern boundary 2 m. 12 c. from its eastern end. This creek courses in a beautiful valley thirty feet deep and eight or ten chains wide, with excellent clay loam soil.

Casual mention was made in the general description of the many fallen trees in the Clay Belt. An area extending two miles south from the northern boundary at a point two miles from its western end illustrates very well the extreme of this condition. In this area there are very few standing trees. In one locality there is a stretch of twenty chains without any. Spruce, poplar and tamarack lay piled over one another, so that for chains at a time one can walk over tree trunks without touching the ground at all. This was the most marked "windfall area" seen in the whole region traversed. The soil was clay loam with boulders in places.

At a point within the township about 5 m. south and 3½ m. west of its northern and eastern boundaries, respectively, there is a hill of rock about one hundred and twenty feet high. From the top of this hill a vast extent of conical tree-tops (black spruce) of a dark green color is seen. Many brown stretches of dead tamarack occur, especially numerous to the westward. The lighter green of the poplar knolls, which appear here and there as islands in a sea of black spruce, adds to the beauty of the scene. The poplar knolls form, apparently about one-tenth of the whole field of vision. The whole surrounding country is very flat, and the horizon consequently an almost unbroken straight line. Here and there in the far-distant south and west, however, it is interrupted by an elevation apparently similar to the one ascended. To the north the surface rises gradually, the horizon appearing not more than three miles away.

TULLY TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	71	6
Poplar knoll	10	11
Muskeg	19	....

Flowing in a northerly and westerly direction are some small creeks, the largest thirty feet wide, the banks of which are low and wooded mostly with spruce. In many places a luxuriant growth of beaver hay, a chain or two wide, borders the streams. The soil in these localities is a very rich clay loam.

This township resembles the preceding ones in its general flat nature.

TOWNSHIP NORTH OF PROSSER

Type.	Per cent.	Trees.
Black spruce forest	85	8 (brulé excepted.)
Muskeg	15	....

The brulé which in the description of Prosser was said to occur on its northern boundary, extends about two miles north into this township, and then sends an arm one-half mile wide in a north-westerly direction across the western boundary. It is thus of considerable size, occupying about one-fifth or one-sixth of the whole township.

A creek, thirty-five feet wide, flows northwest across the eastern boundary 3 m. 45 c. from its southern extremity. Its banks, of clay loam, are fifteen feet high, and wooded with fair-sized black and white spruce. A creek of about the same size, flowing north, was crossed on the north boundary 1 m. 22 c. from its western extremity. At this point it has low swampy banks, bordered with alder.

TOWNSHIP NORTH OF TULLY

Type.	Per cent.	Trees.
Black spruce forest	70	8
Poplar knoll	14	13
Muskeg	16	....

The surface of this township is inclined to be rolling. In the northern part are several small lakes, with banks twenty or thirty feet high, well timbered with poplar averaging sixteen inches in diameter; white spruce, fifteen inches; birch, ten inches; and some black spruce. Some areas, especially in this part of the township, are admirably adapted to suit the needs of the farmer.

REGION NORTHWEST OF PROSSER

Type.	Per cent.	Trees.
Black spruce forest	93	7
Muskeg	7	....

This unsurveyed area was traversed as follows: (1) West from the northwest corner of Prosser, 3 m.; north, 1 m.; east, 3 m. (2) West from the west boundary of the township north of Prosser, 3 m.; north of the termination of the first trip, 3 m.;

north, 2 m.; east, 3 m. Thus this region lies west of the western boundary of the township north of Prosser, and is three miles wide.

As the table shows, this area is very largely a spruce forest, but among the black spruce there are a good many dead tamarack. In fact, in the southern part there are some stretches of tamarack swamp. Doubtless the surface is better drained farther west nearer the Mattagami river.

SECOND TOWNSHIP NORTH OF PROSSER

Type.	Per cent.	Trees.
Black spruce forest	78	7 (brulé excepted)
Poplar knoll	5	11
Muskeg	15	.....
Rock	2	.....

Occupying a very large proportion of the western half of this township, is an area of brulé about thirty years old. At the present time this area is a small spruce and tamarack thicket, growing on a clay subsoil, which is overlaid by one to three feet of black mould. This brulé crosses the western boundary, beginnnig 20 c. from its southern end, and continuing north for 1 m. 70 c. It also extends across the southern boundary beginning 1 m. 20 c. from its western end and continuing east for 40 c.

There is a gradually rising granite hill, eighty feet high, at a point within the township 3 m. 40 c. north and 2 m. west. The sides of this outcrop which extends about 30 c. from north to south, are wooded with black and white spruce, averaging fifteen inches in diameter; white birch, fourteen inches; and cedar, twelve inches. Particularly interesting as far as this report on the timber is concerned is the fact that on this hill are seven white pine (*Pinus strobus*), the largest twenty-two inches in diameter. This is one of the very few clumps of white pine seen during the whole summer. The thin covering of soil about this outcrop consists in some places of a white powdery clay, and in others of a light white sand.

The creeks of this township are about the same size as those in the one to the south, and indeed are probably continuations of them. They will be valuable agriculturally.

SECOND TOWNSHIP NORTH OF TULLY

Type.	Per cent.	Trees.
Black spruce forest	71	7
Poplar knoll	20	14
Muskeg	9	.....

The black spruce forest of this township is more broken than usual by areas of dead tamarack. Fallen trees, too, are rather exceptionally numerous.

Near the middle of the township there is an area of dry rolling land, mostly clay loam, but in some places sandy, which is wooded with many large white birch, averaging fifteen inches; white spruce, fifteen inches; some poplar and balm, fourteen inches; and a thick undergrowth of mountain maple and hazel. This area was entered at a point 2 m. from the western boundary, and 4 m. 19 c. from the southern and continued north for 41c. It stretches a mile to the east, and in this part there are four small lakes, with banks in some places about fifty feet high, wooded with timber like that just described. Around these lakes are some good cedar, the best seen during the whole summer, many trees being sixteen inches in diameter.

LITTLE TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	56	8
Poplar knoll and river bank	15	14
Muskeg	16	....
Jack pine area	13	5-6

The Frederick House river flows almost diagonally through this township, from southeast to northwest. In this part of its course it is about two chains wide, and has a sluggish current, unbroken by any rapids. For the first mile it has low swampy banks wooded with ten-inch black spruce, but for the rest of its course in this township its banks are from thirty to forty feet high, of good clay loam, and well wooded with poplar and balm of Gilead, sometimes twenty inches in diameter, but averaging sixteen, and white spruce, sixteen inches. This timber and soil extend inland about twenty chains.

The southern boundary of Little extends for 1 m. 15 c. from its eastern end through spruce woods. The trees average eight inches in diameter, and grow on a clay subsoil, overlying which is a foot of black mould. The next 47 c. extend over a small muskeg, and the rest of the southern boundary through a jack-pine area, in which is an occasional small muskeg with a sand bottom. This area was burned over about fifteen years ago, and is now wooded with small trees, five or six inches in diameter. As usual in jack-pine areas the soil is a very light sand, and of no value agriculturally. Toward the western end of this boundary there are several sandy hills covered with young white birch and jack-pine. The jack-pine region extends in a northwesterly direction from the point where it begins on the southern boundary, *i. e.* 1 m. 62 c. from the eastern side of the township, for a distance of about three miles. It is, however, broken by small areas of muskeg (probably with sand bottoms), tamarack swamp, and one small rock outcrop. Thus the southwest corner of Little, an area probably about one-fifth to one-quarter of the township, is of no value for farming purposes.

MANN TOWNSHIP

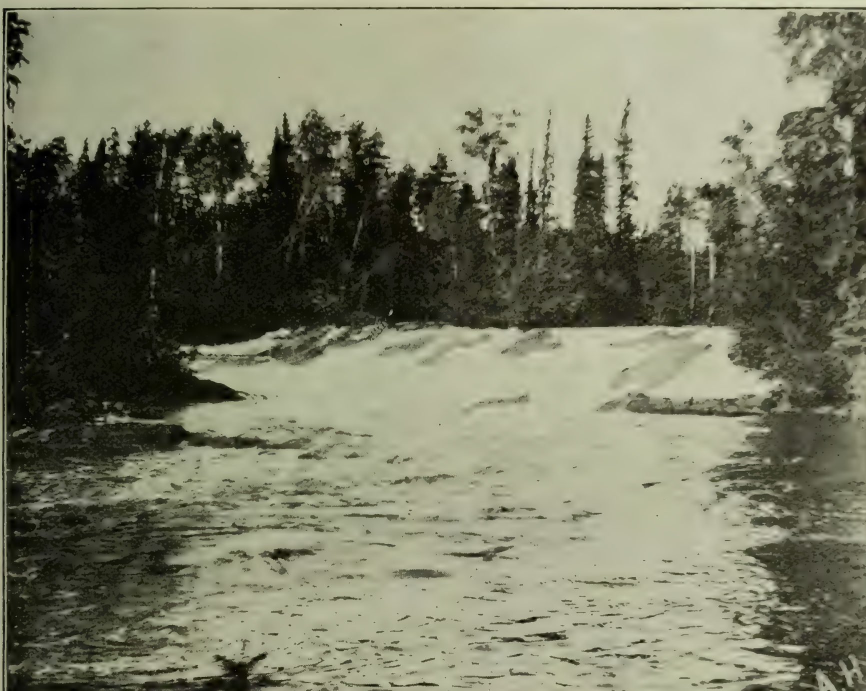
Type.	Per cent.	Trees.
Black spruce forest	66	7 (brulé excepted.)
River bank and poplar knoll	26	12 (brulé excepted.)
Muskeg	8	....

The Frederick House river runs north through Mann township a short distance from its western boundary. Its banks are here about thirty feet high and for the southern two miles well wooded with the two poplars, spruce and balsam. This timber extends about thirty chains inland. For the northern four miles, however, its banks are covered with small poplar, spruce, balsam and birch, about thirty years old.

The first falls on the Frederick House occurs just within the southern boundary of Mann. Here there is a drop of forty-six feet, which would afford valuable water power.

A large proportion of this township was burned over about thirty years ago, and is now wooded with spruce and tamarack, five to six inches in diameter, and poplar, six to eight inches. The brulé extends to the river banks, as mentioned above, along the northern four miles of its course through this township. It reaches a short distance across the northern boundary beginning 2 m. 17 c. from its western extremity,

and continuing east for 3 m. 43 c. It appears also on the southern boundary, beginning 1 m. 30 c. east of the river and extending east to the edge of a large muskeg. This muskeg occupies the southeastern corner of the township, and in extent is about one mile from east to west, and a mile and a half from north to south. It is over seven feet deep and would thus afford a considerable supply of peat.



Falls on Frederick House river, Mann Township. One of upper cascades.

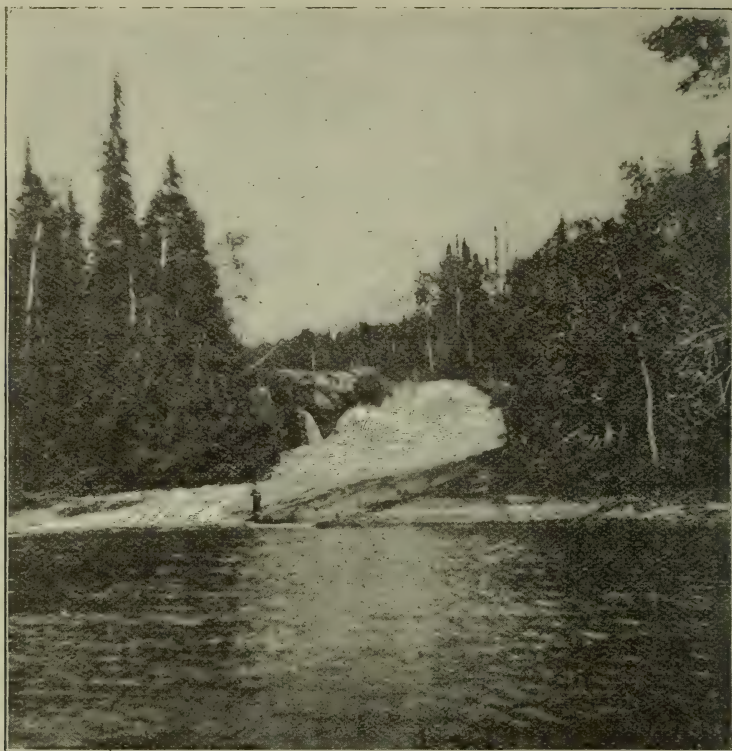
The labor of clearing the land in this township will be reduced to a minimum on account of the large amount of brulé. The soil is the usual clay loam, and the drainage is good.

TOWNSHIP NORTH OF MANN

Type.	Per cent.	Trees.
Black spruce forest	60	8
River bank and poplar knoll	27	14
Muskeg	13	....

The Frederick House river continues its northerly course through this township, and, as in Mann, flows quite near the western boundary. Its banks are about thirty-five feet high and are wooded with a strip, ten to twenty chains wide, of spruce, averaging fifteen inches in diameter; birch, ten inches; poplar, fourteen inches; balsam and balm of Gilead, eleven inches. Thus there are more birch here than usual.

The soil is sandy in many places, and in one locality, ten chains north of the southern boundary, where the bank is quite steep, the soil on the summit is a sand loam, while half way down the slope it is clay. In many other localities throughout the whole of the region traversed, where sand was found on the surface, the under-



Falls on Frederick House river, Mann Township. Lower western cascade.

lying soil, often only a rew inches below, was found to be clay. Thus, while sometimes heavy poplar were apparently growing on sandy soil, closer examination usually revealed the fact that the sand was a surface-covering only a few inches in thickness. This is the case, for example, on Couchiching Falls portage.

A creek, one chain wide at its mouth, empties into the Frederick House forty chains south of the northern boundary of the township. This creek was ascended in a southeast direction for two miles and a half, where farther passage was blocked by driftwood, the creek now being narrowed to thirty feet. It has clay loam banks, ten to twenty feet high, wooded with spruce, balsam, poplar and some birch.

The brulé of Mann township which has been said to extend across the northern boundary into this one, did not appear on an east and west exploration line two miles north of the southern boundary. Thus the brulé cannot extend far into this township.

The fact that there is an unusually large number of fallen trees in this township should be mentioned. Their presence will considerably increase the difficulty of clearing the land.

SECOND TOWNSHIP NORTH OF MANN

Type.	Per cent.	Trees.
Black spruce forest	55	8 (brule excepted.)
Poplar knoll	34	13
Muskeg	11	....

A large proportion of this township was burned over about forty-five years ago. Hence much of the fifty-five per cent. of spruce forest is a small spruce and tamarack thicket, but the remainder is of trees averaging eight inches in diameter. The poplar knolls, too, are largely brulé, but the trees have grown remarkably quickly, and average thirteen inches in diameter. One, which measured fifteen inches, had only forty-three rings of growth. It was a perfectly solid tree, forty feet high. The soil is a rich clay loam.

This township seems to be fairly well drained, having a rolling surface, and some streams of moderate size. The Frederick House river flows northwest across its southwestern corner, crossing the western boundary one mile from the corner, *i. e.*, at m. 157 on Niven's line.

McCART TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	56	11
Poplar knoll and river bank	10	11
Muskeg	12	....
Jack pine area	20	10
Rock	2	....

The surface of McCart township is inclined to be rolling in nature. The streams are of fair size, one in the middle of the township, being fifty feet wide. Along these streams are many large white spruce, some even twenty-nine inches, but averaging seventeen, and some birch, but very few poplar.

The middle two miles of the eastern boundary run through jack-pine country, which has within its limits several small lakes. These are bordered by sandy and gravelly banks, thirty to forty feet high, wooded with jack-pine and white birch. This area extends in a southwesterly direction until it reaches the southern boundary along the eastern end of which it extends for two miles. The trees of this area will make good railway ties.

Within the township about one mile north and three miles east is a ravine of glacial origin, with banks about sixty feet high, composed of coarse sand, gravel and boulders. The value of such a deposit in an almost wholly clay country is self-evident. In this locality the timber is very heavy, white spruce, twenty inches in diameter, and white birch, sixteen inches, being very numerous. These birch were the largest seen during the whole summer. In this township the white birch is quite often found growing in the black spruce forest. A few large yellow birch (*Betula lutea*) were seen along the southern boundary, but this tree is of rare occurrence in the region traversed.

While the more valuable timber trees, white spruce and white birch, are more numerous and of a larger size than usual, the opposite is true of the poplar. As this fact would indicate, the soil is lighter than is usual, there being a considerable amount of sand loam in McCart, besides the exceedingly light soil of the jack-pine area in the eastern part of the township.

NEWMARKET TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	58	7
Poplar knoll	16	10
Muskeg	26	....

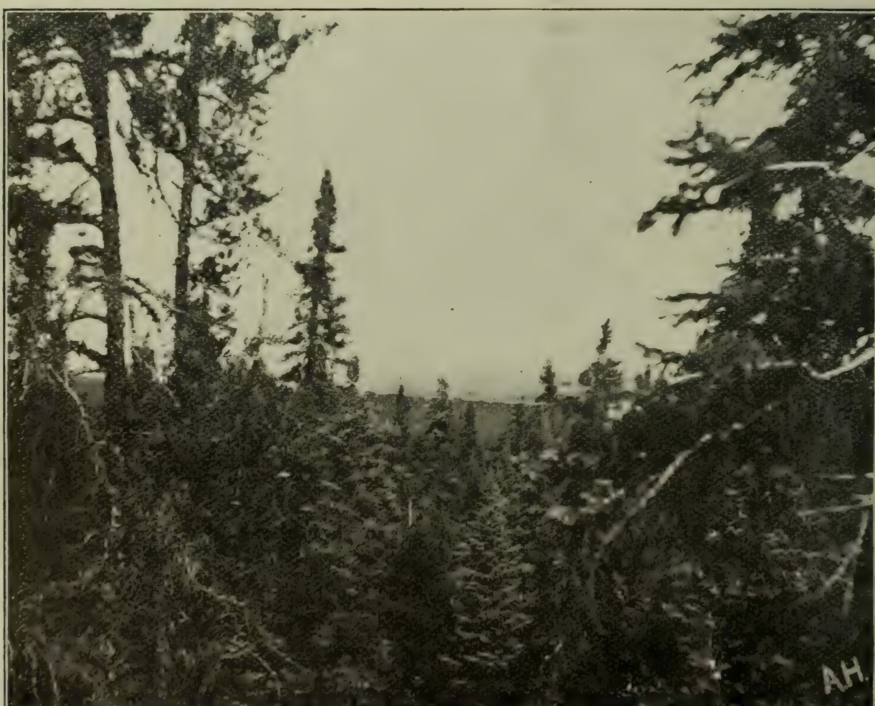
The black spruce forest of this township is considerably broken by areas of tamarack swamp, in which there is now a very dense growth of heavy alder.

The central part of the township has a rolling surface, and here white spruce and poplar are scattered through the black spruce forest. This part of the township, with its beautiful valleys will make exceptionally good farming country.

CALVERT TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	33	11
Poplar knoll and river bank	43	15
Muskeg	5	....
Jack-pine area	17	12
Rock	2	....

The Abitibi river flows north through Teefy township, about one-half mile from the eastern boundary of Calvert. Near the northwest corner of Teefy it takes a turn to the northwest and flows across the corner of this township. The river bank type of soil and timber extend inland in this part of the course of the Abitibi about three-



Black spruce forest, looking north from top of rocky hill. Calvert Township.

quarters of a mile. Consequently, the eastern part of Calvert is well drained, has numerous ravines, some forty to fifty feet deep, and is heavily timbered. Deep ravines are characteristic of townships on the Abitibi river, and the banks of these in nearly every case are heavily wooded with poplar, white spruce, balsam, black spruce and balm of Gilead. Jack-pine and white birch occasionally occur in parts having a light

soil. Thus in the poplar areas in the eastern part of this township there are many large white spruce eighteen inches in diameter, but averaging about sixteen, besides the poplar, which average eighteen inches.

The jack-pine plain, which in the description of McCart township was said to stretch along the middle two miles of its eastern boundary extends into this township in a northeast direction. Along the line between concessions five and six it extends for 2 m. 55 c. The trees average twelve inches. Along this line one mile and three-quarters from the western boundary the jack-pine plain is broken by a rocky hill about one hundred feet high. Owing to the covering of black spruce and jack-pine on this hill a good view of the surrounding country could not be obtained. What could be seen to the north appeared to be nearly all black spruce forest.

AURORA TOWNSHIP

Type.	Per cent.	Trees
Black spruce forest	73	9
Poplar knoll and river bank	17	13
Muskeg	10	....

The Abitibi river flows north through the middle of this township. Above the Buck Deer rapids the banks are quite low, and are wooded with black and white spruce, averaging fifteen inches, birch and balsam. The soil here is sandy and

Abitibi river bank just above Buck Deer Rapid, Aurora Township.

poor in humus and other constituents of value, as the chemical analysis shows—an unusual condition on a river bank. From the Buck Deer rapids to the northern

boundary the river banks are much higher, and are wooded in the ordinary way, *i. e.*, with good poplar and large white spruce predominating. Some fair sized cedar, many trees fifteen inches in diameter, also occur.

Inland from the river the township is largely of the black spruce forest type. The trees, though of a fair size, averaging nine inches, are rather scattered, as there are a great many "windfalls" in this township. The soil is for the most part the usual clay loam.

TEEFY TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	32	11
River bank and poplar knoll	62	18
Muskeg	1	....
Jack pine area	5	....

The Abitibi river flows through Teefy township in a course shaped like a horseshoe, with the concavity directed northward. Toward the eastern side of the township the banks are rather steep, about seventy feet high, and wooded with poplar, some twenty-nine inches in diameter, but averaging eighteen; black and white spruce,

Iroquois Falls, western division, Teefy Township.

fifteen inches; balm of Gilead, sixteen inches; balsam and occasional birch and jackpine. Along the western part of its course the river has lower and more gradually rising banks, beautiful slopes with timber and soil as in the other part. In this western part Iroquois falls, fifteen feet high occur. These falls will be a source of

Iroquois Falls, western and central divisions, Teefy Township.

valuable water power. The river banks, in both the eastern and the western parts of its course, are broken by numerous ravines, the depth varying with the height of the banks. Many of them have steep sides.

Abitibi river bank near north-east corner of Teefy Township.

A very rich clay loam soil is common to the sixty-two per cent. of the township covered with river bank and poplar knoll timber. The river bank timber extends inland from one to two miles, and farther inland are many poplar knolls with timber and soil like that of the river bank.

The jack-pine occur along the eastern boundary beginning ten chains south of the river, and extending south for 1 m. 12 c. Some white birch, black and white spruce and balsam are associated with the jack-pine in this locality. Three small lakes occur along this boundary.

EDWARDS TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	64	9 (brulé excepted)
Poplar knoll	22	13
Muskeg	13	....
Rock	1	....

An area of brulé twenty to thirty years old occupies the northeast quarter of this township. Throughout the brulé there are occasional small islands of the original forest. Elsewhere it is a small spruce and tamarack thicket, with few poplar and birch.

On the northern boundary 2 m. 20 c. from its eastern end there is a hill of rock about sixty feet high. From the top of this hill the country to the north appears to be almost wholly black spruce forest, while to the south there is a considerable proportion of poplar knoll, indicating better drainage in that direction.

The muskeg, it would seem, is for the most part near the center of the township.

RICKARD TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	38	10
River bank and poplar knoll	53	16
Muskeg	4	....
Jack-pine area	5	... .

The Abitibi river pursues a westerly course near the northern boundary of Rickard township. Its banks are lower and more gradually sloping than in the eastern part of Teefy, the adjoining township to the west. Ravines, similar to those in Teefy, occur along the river banks, but are not so numerous nor so deep. The river bank timber and also that of the inland part of the township resembles the timber of Teefy, but is not quite so heavy.

The jack-pine area occurs along the western boundary, and has been referred to in the description of Teefy.

WESLEY TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	42	8 (brulé excepted)
Poplar knoll and river bank	48	15 (brulé excepted)
Muskeg	10	....

Flowing in a southwesterly direction, almost diagonally across Wesley township, is the Misto-ogo river, a tributary of the Abitibi. This river is about one chain wide in the centre of the township. Some of its branches flow through beautiful valleys.

The brulé, which has been said to occupy the northeastern part of Edwards, is also present in this township, and here, too, is of considerable size. It was seen in the following localities: (1) On the western boundary, from a point 40 c. from the northwest corner of the township, extending south 2 m. 10 c. (2) On the eastern boundary, from a point 1 m. 17 c. from the southeastern corner of the township,

extending south 1 m. 73 c. It thus reaches into Rickard and Knox for a short distance. (3) On a north and south line, 2 m. from the eastern boundary, beginning 3 m. 10 c. from the northern boundary, and extending south for 1 m. 59 c.

Thus there appears to be a strip of brulé about two miles wide extending across the township from southeast to northwest. Most of this is of the poplar knoll type.

KNOX TOWNSHIP

Type.	Per cent.	Trees.
Black spruce forest	26	8
Poplar knoll and river bank	70	15
Rock	4	....

The Abitibi river flows westerly through Knox, slightly north of the middle of the township. Its banks are similar to those in Rickard, both in soil and timber.

Along the southern half of the eastern boundary and the eastern half of the southern boundary are several low rocky ridges wooded with black spruce and white birch. In the intervening valleys the soil is clay loam on which grows poplar, spruce, balsam and balm. Occasionally sandy soil occurs, and here white birch of a fair size is found growing with the black spruce.

At a point 2 m. 48 c. west and 58 c. to 75 c. north is a rocky hill, one hundred and fifty feet high. The nature of the country as indicated by the view from this hill contrasts very favorably with that of the area about the similar hill in Prosser. In the latter case most of the country visible was a black spruce forest with stretches of dead tamarack and occasional poplar knolls. In this case, on the other hand, the surrounding country is almost wholly wooded with poplar, and there is only here and there a small area of black spruce. This township thus, as indicated by its timber, is well drained, and although the large number of fallen trees will render clearing difficult, it will be especially valuable from the agricultural standpoint.

MOODY TOWNSHIP

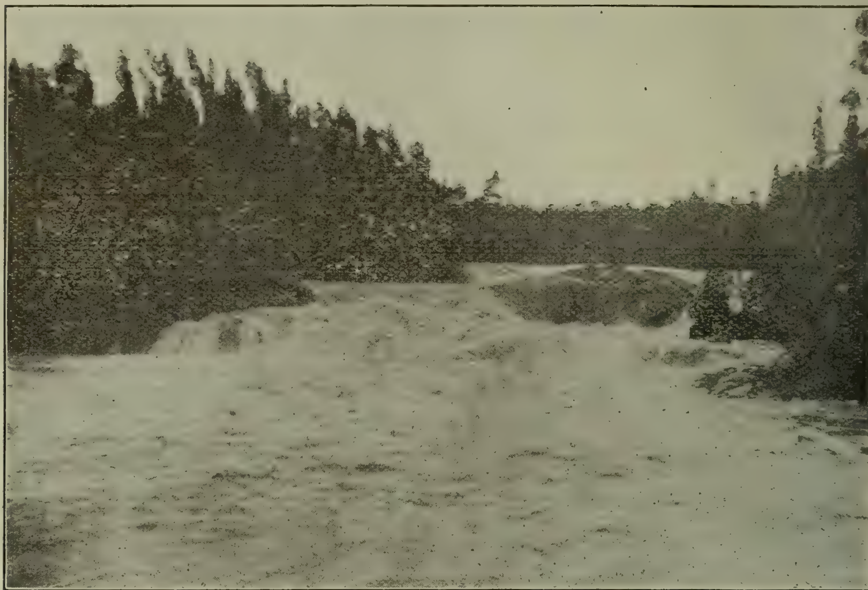
Type.	Per cent.	Trees.
Black spruce forest	49	7
Poplar knoll	21	14
Muskeg	20	....
Jack-pine area	10	11

As these percentages indicate, Moody township is poorly drained. A large muskeg extends south from the middle point of the township for 2 m. 27 c. In the centre it is at least a mile wide, and is over seven feet deep.

Along the eastern boundary on the second and third miles from its southern end, are several narrow jack-pine ridges, the trees averaging from ten to twelve inches in diameter.

TOWNSHIP EAST OF KNOX

Type.	Per cent.	Trees.
Black spruce forest	42	8
River bank and poplar knoll	53	15
Muskeg	2	....
Jack-pine area	2	....
Rock	1	....



Couchiching Falls, Abitibi river.

Couchiching Falls, Abitibi river, upper drop.

The Abitibi flows west about three miles north of the south boundary of this township. Its banks are about thirty-five feet high, and are of the ordinary type, clay loam wooded with poplar and spruce chiefly. Couchiching Falls, thirty-five feet high, occur about one mile and a half from the western boundary and would afford valuable water power.

Flowing into the Abitibi from the south about three miles from the western boundary is a beautiful stream of clear water, the Dokis creek, one chain wide at its mouth. Its banks are from ten to fifteen feet high, are of clay loam and well wooded.

Some areas of sand loam occur in this township, *e. g.*, along the southern boundary. On this boundary, too, 4 m. 7 c. from the western end, there is a spring of sulphur water which deserves mention.

Only the western and northern boundaries of this township have been run.

TOWNSHIP EAST OF MOODY

Type.	Per cent.	Trees.
Black spruce forest	57	7
Poplar knoll	18	14
Muskeg	12	....
Jack-pine area	13	....

The immediate shore of lake Abitibi, which adjoins the eastern side of this area, is for the most part very rocky though in some places sandy, and in others swampy. The neighboring bank is from thirty to fifty feet high, and is wooded with spruce, birch, jack-pine, poplar and balsam, growing mostly on a sandy soil.

The northern part of this area, that which is drained by the Dokis river, is from the agricultural standpoint, the most valuable.

Only the western and northern boundaries of this township have been run.

THIRD TOWNSHIP NORTH OF TULLY

The number of miles travelled in this township (and also in the next one), is so much smaller than usual (the average being 20 m. 58 c.), that it will not justify the drawing up of a percentage table.

The Frederick House river flows northwest across the eastern boundary one mile from its southern extremity, and continuing its northwesterly course crosses the north boundary at its middle. For the northern two miles its banks are about thirty-five feet high, of a clay loam soil, and are wooded with large poplar, spruce, balsam and some balm, and birch. At the northern boundary this timber extends inland fourteen chains on the west side of the river. For the rest of its course in this township the banks are lower, are of a sandy soil, and are wooded with spruce, birch, balsam and few poplar.

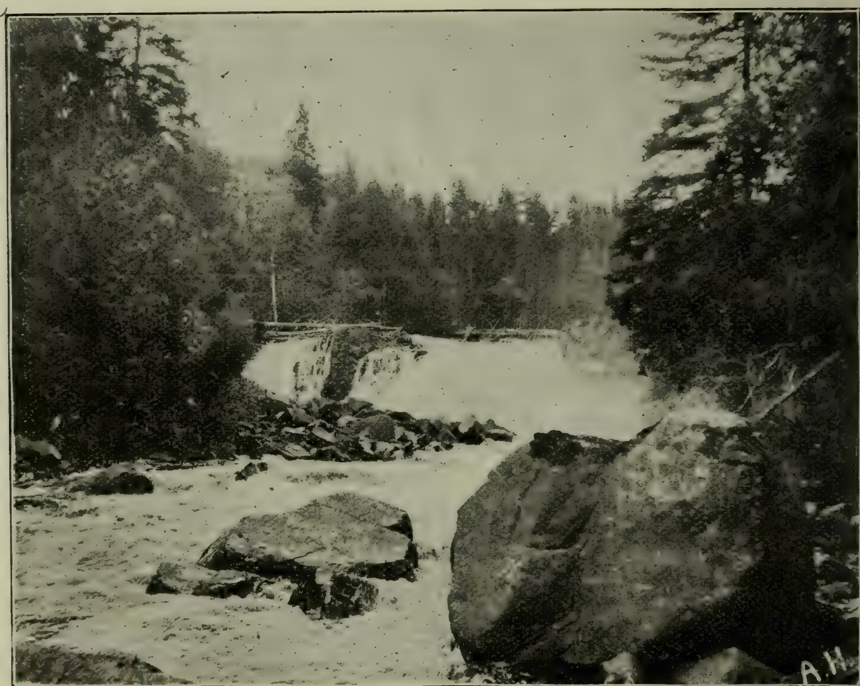
Several lakes in this township have steep banks, forty feet high, wooded with large spruce, poplar and birch. These lakes would appear to form part of a chain of small lakes about one mile west of the river.

Inland the township is largely of the black spruce forest type, with trees averaging seven inches in diameter.

THIRD TOWNSHIP NORTH OF PROSSER

Flowing north through this township and crossing its northern boundary 1 m. 24 c. from its eastern extremity is a river two chains wide, with banks about twenty-five feet high, wooded as usual. The trees here however are young ones, one poplar seventeen inches in diameter having only forty annual rings—a remarkably quick

growth. The brulé, of which these large poplar trees form a part, extends along nearly all of the northern boundary, and is mostly a small spruce and tamarack thicket. One of the finest poplar knolls seen during the summer, however, is included in this brulé, and occupies the northwestern corner of the township. The trees average twelve inches in diameter, are about forty years old, and there is scarcely a fallen tree



Falls on Montreal River at Great Northern Bend.

in the whole area. Only small stretches of this brulé were seen on an east and west line three miles south of the northern boundary. This line extended for the most part through wet spruce woods, the trees averaging six to seven inches in diameter. Here and there however were small areas of muskeg.

II. CLIMATE

Temperature

An accurate record of the temperature was kept during the four months in the Clay Belt. The minimum temperatures were registered by a minimum thermometer, and the readings were made about seven a. m. The temperatures noted between one and two p. m. are approximately the maximum. In addition to the minimum and maximum temperatures a reading was made in the evening about half-past eight o'clock.

These temperatures are presented in the following table, together with some notes on the amount of rainfall and sunshine, and the relative velocity and direction of the winds.

JUNE

Date.	Minimum.	Maximum	8.30 p.m.	Rain, sunshine, winds.
3	37	....	63	Clear.
4	43	....	....	Cloudy, showers in morning and evening.
5	47.5	66	....	Cloudy.
6	52	67	....	Cloudy, showers at intervals.
7	48	....	57	Cloudy, rain all morning.
8	30	....	68	Clear, strong N. W. wind.
9	42	76	62	Clear.
10	38	82	70	Clear.
11	39	80	....	Clear.
12	42	86	68	Cloudy in evening.
13	49	76	68	Mostly clear. rain at night.
14	45	66	58	Rain until 11 a.m.. Showery after. Strong N. W. wind.
15	42	58	52	Cloudy. N. W. wind.
16	37	76	64	Clear. N. W. wind.
17	36.5	61.5	59	Cloudy, shower from 3 to 4 p.m., with thunder in distant west. S. E. breeze.
18	42.5	60	50	Clear. S. W. breeze.
19	33.5	84	63	Clear.
20	51	82	70.5	Clear. N. W. breeze.
21	52	62	46	Cloudy. Strong N. E. Wind.
22	28	64	52	Clear.
23	37	75	70	Clear.
24	57	75	74	Cloudy, showers after 4 p.m. Strong S. W. wind.
25	56	77	70	Cloudy.
26	56	62	49	Passing clouds. Very strong S. W. wind Dead tamarack blowing down about camp.
27	39	74	61.5	Clear. Strong N. W. wind.
28	40	73	64	Clear. Strong S. W. wind.
29	40	71	60	Showers after noon. N. W. wind.
30	50	74	56	Cloudy. Showers in a.m. Strong northerly wind.

JULY

Date.	Minimum.	Maximum.	8.30 p.m.	Rain, sunshine, winds.
1	39	62	53	Clear. N. W. wind.
2	39	57	60	Clear. N. W. breeze.
3	38	75	59	Clear. Strong S. W. wind.
4	48	60	54	Cloudy. S. W. breeze. Shower at night.
5	43	64	52	Cloudy at intervals.
6	40	68	44	Clear.
7	33	84	64	Clear.
8	42	81	63	Clear.
9	58	66	64	Rain until 2 p.m., cloudy afternoon.
10	58	78	58	Clear. N. W. breeze.
11	48	70	68	Clear.
12	52	52	45	Cloudy. Showers after noon. S. E. breeze.
13	36	77	63	Cloudy. Shower about 2 p.m.
14	39	78	69	Cloudy after noon.
15	56	70	67	Showery.
16	47.5	67.5	62.5	Cloudy in a.m. N. W. breeze.
17	50	87	62	Thunder storm in early morning. Clear after 7 a.m.
18	42	84	78	Clear. W. breeze.
19	65	80	64	Clear.
20	42	65	56	Clear. N. W. breeze.
21	33.5	68	51	Mostly clear. Showery in p.m. N.W. breeze.
22	30	61	48	Clear.
23	26	76	56	Clear.
24	33	75	62	Clear.
25	50	77	62	Clear.
26	55	80	58	Clear.
27	56	72	65	Showery.
28	46	60	52	Cloudy. W. breeze.
29	37	74	62	Clear. S. W. breeze.
30	40	60	60	Cloudy, rain all morning.
31	52	74	56	Clear. Strong S. W. wind.

AUGUST

Date.	Minimum.	Maximum.	8.30 p.m.	Rain, sunshine, winds.
1	43.5	58	50	Mostly clear.
2	35	74	60	Cloudy after noon and two showers.
3	43	72	59	Clear.
4	48	76	68	Cloudy after noon.
5	57	66	60	Rain in morning. Strong S.W. wind.
6	50	51	50	Rain all day. Strong S.W. wind.
7	44	58	45	Showery.
8	36	70	60	Mostly clear.
9	36	68	54	Clear.
10	50	56	50	Showery.
11	39	69	55	Clear.
12	46	66	59	Mostly clear. Rain at night.
13	52	70	52	Cloudy.
14	46	60	42	Cloudy in p.m.
15	31	59	50	Cloudy towards evening.
16	40	56	52	Clear in p.m. Strong W. wind.
17	39	56	46	Showery.
18	33	65	57	Showery after 3.30 p.m.
19	39	65	60	Clear.
20	48	72	62	Mostly clear.
21	46	72	68	Cloudy. Rain at night.
22	54	59	46	Cloudy in a.m. S.W. wind.
23	36	66	67	Clear. Strong S.W. wind.
24	58	67	62	Cloudy. Rain at night.
25	57	67	41	Showery. Very strong W. wind.
26	41.5	66	53	Clear.
27	45	77	60	Mostly clear. Thunder shower about 4 p.m. W. breeze.
28	53	66	48	Clear. Showery in evening.
29	28.5	60	45	Clear. Showery in evening.
30	36	53	43	Clear.
31	27	60	52	Clear. W. breeze.

SEPTEMBER

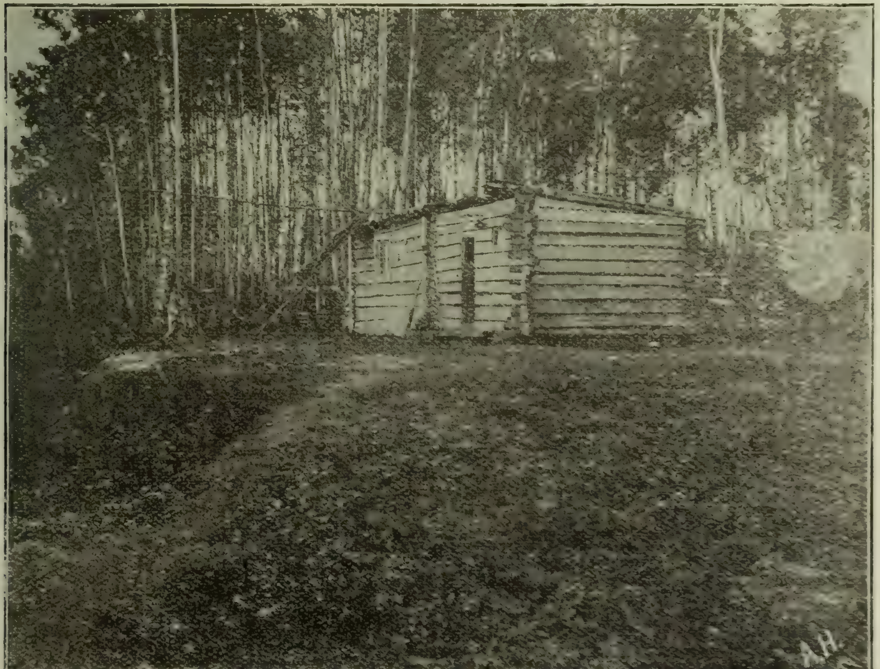
Date.	Minimum.	Maximum	8.30 p.m.	Rain, sunshine, winds.
1	43	62	50	Cloudy, drizzling in a.m.
2	39	56	43	Rain in p.m.
3	42	62	56	Rain all day. An autumn day.
4	44.5	56	46	Showery.
5	32	51	42	Clear.
6	27	62	53	Clear. N.W. breeze.
7	43	68	48	Mostly clear.
8	33	56	46	Mostly clear.
9	44	61	57	Mostly clear.
10	50	74	68	Cloudy after 2.30 p.m.
11	52	43	46	Cloudy. N.W. breeze.
12	33	50	37	Cloudy at intervals.
13	27	50.5	46	Cloudy. Rain at night.
14	41.5	52	45	Rain in a.m. N.W. wind.
15	34	56	41	Mostly clear.
16	35.5	54.5	42.5	Showery. Strong N.W. wind.
17	30.5	51.5	48.5	Rain. N.W. breeze.
18	37	46	33	Rain.
19	25.5	43	38	Cloudy.
20	31.5	38.5	34	Snow flurries. Strong N.W. wind.
21	30	41.5	37	Mostly clear. Occasional snow flurries.
22	25	54	36	Clear.
23	33	46	50	Steady rain.
24	43.5	51	45	Cloudy, drizzling after 2 p.m.
25	32	43	41	Cloudy.
26	40.5	44.5	35	Cloudy until 3 p.m.
27	29	55.5	40	Clear.
28	32	67	55	Clear. Rain at night.
29	48	62	56	Cloudy. Rain before 8 a.m. W. wind.
30	45.5	48	46	Showery after noon. Very strong N.W. wind.

The next table gives the average daily minimum and maximum temperatures for each month, and the monthly extremes of the summer of 1904, in the Clay Belt and in the vicinity of Guelph. These latter figures were kindly supplied by Professor Reynolds of the Ontario Agricultural College.

TEMPERATURE OF CLAY BELT AND GUELPH

Month	Region	Mean daily Minimum	Mean daily Maximum	Monthly Minimum	Monthly Maximum
June.........	Clay Belt...........	43.42	71.98	28.00 on 22nd	86.00 on 12th
	Guelph.............	52.00	73.26	41.50 on 23rd	84.00 on 25th
July.........	Clay Belt...........	44.32	70.95	26.00 on 23rd	87.00 on 17th
	Guelph......... ...	54.87	77.15	42.00 on 3rd	90.25 on 18th
August.......	Clay Belt.	43.14	64.58	27.00 on 31st	77.00 on 27th
	Guelph.............	52.01	74.77	42.00 on 9th	84.00 on 13th
eptember...	Clay Belt...........	36.78	53.75	25.00 on 22nd	74.00 on 10th
	Guelph.............	48.36	67.23	30.00 on 22nd	81.5 on 2nd and 3rd

On comparing the Clay Belt temperatures with those of southern Ontario, it will be observed that there is little difference between the maximum temperatures in the two regions for the months of June and July. The minimum temperatures, however,



Indian hut and potato patch, west shore of Frederick House Lake.

differ considerably. This would be expected as many of the readings were made in wet spruce woods, in some of which, even in the late summer, ice was found only a foot or two below the surface of the moss. The minimum temperature registered at

night would be much more affected by the proximity of this ice than the maximum taken between one and two o'clock, when the heat of the sun is greatest. When the country is cleared this ice will melt in the spring, and the minimum temperatures will be considerably higher.

There is reason to believe, however, that the summer of 1904 was unusually cold in the clay belt. Mr. T. B. Speight, O.L.S., in the report of his explorations in this region in 1900, says that only two frosts occurred during the whole of that summer. Again, Mr. G. F. Kay, B.A., reports concerning the temperature of the same region for the summer of 1903,that no frosts occurred between 17th June and 1st September.

The whole region which this report concerns is south of the forty-ninth parallel cf latitude, which constitutes the southern boundary of Manitoba. Hence, from considerations of latitude there is no reason why the climate of this region should be more severe than that of southern Manitoba.

That certain vegetables and fruits can be grown in this region even at the present time is known by experiment. An Indian who lives on the western shore of Frederick House lake has fair success in raising potatoes, even though he merely throws the seed on the ground, covers it with a little soil, and then pays no attention to his garden until he digs up his crop in the autumn. At Fort Matachewan, according to Mr. Lafracain, potatoes grow well, as also rhubarb, lettuce, radishes, onions, carrots and cabbages. Some seasons pumpkins and cucumbers do well. Mr. Miller, of Fort Mattagami, tells a similar story. He has succeeded in growing some cf the smaller fruits as well as many vegetables.

Rainfall

June and July in the Clay Belt in the summer of 1904 were good growing months, with plenty of sunshine and a sufficiency of rain. August was a duller month, and had a greater rainfall. September was a very wet month with numerous rain storms, and, on the twentieth and twenty-first days, snow flurries. It is an interesting fact that thunder storms were noted on only three occasions, 17th June, 17th July, and 28th August, and these were of the mildest possible nature, when compared with the frequently heavy electrical storms of southern Ontario.

Seasons

Mr. James Miller and Mr. S. Lafricain, Hudson Bay Company factors at Forts Mattagami and Matachewan respectively, say that winter sets in about the middle of November, and that the snow disappears and the ice breaks up about the end of April or early in May. The snowfall amounts to three or four feet. Thus it would seem that winter in this part of the Province is not much more severe than was that of 1903-1904 in southern Ontario, and that it resembles very much the ordinary winter of Manitoba.

The Clay Belt summer is somewhat shorter than that of southern Ontario. The fact that it is about three weeks later is shown in the list of flora, which gives dates of flowering of plants in both parts of the Province. The early autumn is shown in the temperature record.

III. FLORA

The plants named in the following list were identified by the aid of Gray's Manual of Botany. In some cases it was impossible to be certain of the diagnosis because of the scant literature at hand, and on account of varieties in the Clay Belt not yet described. The names of such plants are marked with an asterisk.

The date of identification, which in most species is approximately the first date of flowering, is given alongside the name of the plant, together with, in many cases, the first date of flowering of the same plant in the vicinity of Guelph. The latter dates were kindly supplied by Mr. A. B. Klugh, secretary of the Wellington Field Natural-

ist Association, to whom I here tender my thanks. A comparison of a large number of the dates of flowering shows that the summer of the Clay Belt is from two to three weeks later than that of southern Ontario.

Flora of the Clay Belt

Plant	Clay belt	Guelph
Sambucus racemosa	June....5	May ...15
Viola blanda	" 6	" 3
Trillium grandiflorum	" 7	" 8
Louicera ciliata	" 7	" 8
Amelanchier Canadensis	" 7	" ...11
Aralia nudicaulis	" 7	June. ..3
Ribes floridum	" 7	May ...22
" cynosbati	" 7	" ...17
" prostratum	" 7	
Menyanthes trifoliata	" 7	" ...23
Actæa spicata, rubra	" 7	" ...30
Claytonia Caroliniana	" 8	Apr....26
Rubus strigosus	" 8	
" triflorus	" 8	May ...23
Caltha palustris	" 8	" 7
Ranunculus abortivus	" 8	" ...15
Trientalis Americana	" 8	" ...27
Mertensia paniculata	" 8	
Streptopus roseus	" 9	" ...27
Salix nigra	" 9	
Trillium cernuum	" 9	
Mitella nuda	" 9	" ...30
Ribes rubrum	" 9	
Anemone nemorosa	" 9	" 3
Andromeda polifolia	" 9	
Smilacina stellata	" ...10	" ...30
Kalmia glauca	" ...10	" ...27
Louicera cœrulea	" ...10	
" involucrata	" ...10	
Ledum latifolium	" ...10	" ...27
Coptis trifolia	" ...10	" ...13
Cornus Canadense	" ...10	June...11
Vaccinium Pennsylvanicum	" ...10	May ...14
Viola rotundifolia	" ...10	
Calypso borealis	" ...10	
Fragaria Virginiana	" ...12	" ...11
" vesca	" ...12	" ...15
*Lathyrus maritima	" ...12	
Clintonia borealis	" ...12	" ...27
Maianthemum Canadense	" ...12	
Sarracenia purpurea	" ...15	June....6
Vaccinium Oxycoccus	" .. 15	" ...26
Comandra livida	" ...15	
Linnaea borealis	" ...16	" ...11
Iris versicolor	" ...16	" 6
Smilicina trifolia	" ...17	May ...27
Cypripedium pubescens	" ...17	" ...30
*Rosa blanda	" ...17	June...13
Geum rivale	" ...17	" 9
Cornus stolonifera	" ...17	May ...26
Osmorrhiza brevistylis	" ...19	June....9
*Ranunculus hispidus	" ...19	
Viburnum opulus	" ...19	
Louicera oblongifolia	" ...20	
Polygonatum biflorum	" ...20	May ...24
Ranunculus Flammula var. intermedius	" ...20	
Pyrus Americana	" ...21	
*Comandra pallida	" ...21	
Oxalis acetosella	" ...21	
Anemone Pennsylvanica	" ...21	
Corydalis glauca	" ...22	
Nuphar advena	" ...22	June...16
Pyrola rotundifolia, incarnata	" ...24	" ...26
Thalictrum polygonum	" ...25	
Galium triflorum	" ...26	" ...14
Pyrola chlorantha	" ...26	" ...14
Cypripedium parviflorum	" ...27	
*Arenaria Grœnlandica	" ...27	
Kalmia angustifolia	" ...30	
Anemone parviflora	" ...30	
Galium trifidum	July 1	" 7
Cypripedium acaule	" 1	" 4
Potentilla Pennsylvanica	" 1	
Pyrola rotundifolia	" 1	
*Louicera Sullivantii	" 1	
Geum strictum	" 1	
Diervilla trifida	" 1	" ...18
Arethusa bulbosa	" 2	July ...28
Goodyera repens	" 2	
Ranunculus septentrionalis	July 4	
Circaea Alpina	" 5	
Potentilla palustris	" 5	June...22
Epilobium augustifolium	" 6	July 6
Pyrola secunda	" 7	
Halenia deflexa	" 7	
Habenaria bracteata	" 7	
Campanula rotundifolia	" 8	June...26
Viburnum cassinoides	" 8	
Pyrola minor	" 8	
Potentilla fruticosa	" ...10	
Pogonia pendula	" ...10	
Cornus paniculata	" ...10	
Habenaria hyperborea	" ...10	
*Epilobium Hornemanni	" ...10	
Sisyrinchium augustifolium	" ...10	
Habenaria dilatata	" ...13	" ...28
*Scutellaria lateriflora	" ...13	
Epilobium lineare	" ...13	
Cypripedium spectabile	" ...14	" ...28
Geum triflorum	" ...14	
*Scutellaria galericulata	" ...14	" ...24
Tofieldia palustris	" ...14	
Moneses grandiflora	" ...18	
Angelica atropurpurea	" ...18	
Monotropa Hypopitys	" ...19	" ...22
Veronica scutellata	" ...21	
Galium asprellum	" ...21	
Nasturtium officinale	" ...21	" ...20
Pogonia ophioglossoides	" ...23	July 5
*Rumex Brittanica	" ...24	
Epilobium coloratum	" ...24	
Monotropa uniflora	" ...24	
Spiraea salicifolia	" ...24	June...29
Mimulus ringens	" ...24	" ...30
Eupatorium ageratoides	" ...24	July ...25
Campanula aparinoides	" ...24	" ...20
Ranunculus circinatus	" ...28	
Lobelia spicata	" ...28	
Polygonum amphibium	" ...28	" ...13
Mentha Canadensis	" ...28	" ...15
Sagittaria variabilis	" ...29	" ...19
Ranunculus Flammula var. reptans	" ...31	
Ranunculus affinis	" ...31	
Aster tardiflorus	Aug 3	
" puniceus var. lucidulus	" 3	
Solidago uliginosa	" 3	
Spiranthes Romanzoffiana	" 4	
Urtica gracilis	" 7	" ...16
Gaultheria procumbens	" 8	
Impatiens fulva	" 9	" ...25
Scutellaria canescens	" 9	
Corydalis aurea	" 9	
Chelone glabra	" ...13	Aug 3
Potentilla tridentata	" ...14	
Bidens cernua	" ...16	
*Hypericum Canadense	" ...16	
Solidago rugosa	" ...16	" 9
Aster macrophyllus	" ...16	July ...25
*Aster Novæ-Angliæ	" ...16	
Stellaria longifolia	" ...17	
Aster multiflorus	" ...25	
Hieracium Canadense	" ...25	
Agrimonia Eupatoria	" ...28	" ...27
Potentilla fruticosa	" ...28	
Prenanthes racemosa	" ...28	
Erigeron acris	" ...28	
Aster paniculatis	Sept ...16	
Betula pumilla		
" glandulosa		
Poa serotina		
Myrica asplenifolia		
Apocynum androsæmifolium		
Calla palustris		
Prunus Pennsylvanica		
Vaccinium uliginosum		
Chiogenes serpyllifolia		
Corylus rostrata		
Typha latifolia		

Rubus chamaemorus.
Crataegus Crus-galli.
Lilium Canadense.
Heracleum lanatum.
Geranium Carolinianum.
Ceratophyllum demersum.

Forest Trees and Shrubs.

Picea nigra.
" " var. rubra
" alba.
Pinus strobus.
" resinosa.
" Banksiana.
Abies balsamea.
Taxus Canadensis.
Larix Americana.
Thuja occidentalis.
Salix nigra (and other sp.)
Populus tremuloides.
" balsamifera.
Corylus rostrata.
Alnus incana.
Betula papyrifera.
" lutea.
Pyrus Americana.
Ulmus Americana.
Fraxinus sambucifolia.
Acer spicatum.

Plants growing in Indian Gardens or on Portages.

Polygonum aviculare.
" dumetorum.
Capsella Bursa-pastoris.
Taraxacum officinale.
Plantago major.
Trifolium repens.
Lepidium Virginicum.
Poa pratensis.
" annua.
" compressa.
Brunella vulgaris.
Erigeron Philadelphicum.
Achillea millefolium.
Graphalium decurrens.
Cnicus arvensis.

Some Cryptograms.

Botrychium Virginianum.
Asplenium Thelypteroides.
Onoclea sensibilis.
Pteris aquilina.
Adiantum pedatum.
Polypodium vulgare.
Osmunda regalis.
Lycopodium annotinum.
" complanatum.
Equisetum pratense.
" palustre.
Marchantia polymorpha.
Many lichens and mosses.

In concluding this section on the flora I would like to call attention to the luxuriant growth of many of the smaller wild fruits. Raspberries in the "windfalls," and red currants in the poplar areas are particularly common, and they attain a size and flavor almost equalling the cultivated fruit of southern Ontario. These fruits ripened about 25 July.

IV. FAUNA

Fur-bearing and Other Animals

This subject has been considered so often that it is hardly necessary to deal with it now. One point of interest, however, must be mentioned, namely, the increase in the number of beaver in this region, beacuse of wise protective legislation. Beaver are now quite numerous in the western part of the region traversed, and, according to the inhabitants of the country they are on the increase.

The skins taken in trade from the Indians at Fort Mattagami during the year ending June, 1904, were, in part, as follows: martin, 300; bear, 15; mink, 300; muskrat, 2,000; otter, 38; red fox, 10; lynx, 7. Besides these animals, fisher and ermine occur.

Of interest to the sportsman is the fact that moose are exceedingly common. While paddling on a little creek that flows into Moose lake, three were seen in one morning. They seem to be particularly numerous in this localtiy. Red deer and caribou also occur, but are not so common as moose.

Fish

The larger rivers and lakes of the region are very muddy, and for this reason the fisherman must use other means than trolling in these waters. The Indians with nets catch large numbers of pike, pickerel, whitefish, and, in some localities, sturgeon. In the smaller rivers and lakes, which usually have beautifully clear water, pike and pickerel are readily caught with a troll.

Birds

The following birds were seen during the summer:

Canada Jay, Perisorens Canadensis.
Bluebird, Sialia sialis.
Black-headed Gull, Larus atricilla.
American Robin, Merula migratoria.
White-throated Sparrow, Zonotrichia albicollis.
Wilson's Thrush, Turdus fuscescens.
American Redstart, Sedeltophaga ruticilla.
Junco, Junco hiemalis.
Indigo Bunting, Passerina cyanea.
Prairie Hen, Tympanuchus Americanus.
Water Thrush, Seiurus Noveboracensis.
Red-eyed Vireo, Vireo olivaceus.
Phoebe, Sagoruis phoebe.
Rusty Blackbird, Scolecophagus Carolinus.
Blackburnian Warbler, Dendroica Blackburniæ.
Prothonotary Warbler, Prothonotaria citrea.
Yellow-bellied Sapsucker, Sphyrapicus varius.
Nighthawk, Chordeiles Virginiaus.
Belted Kingfisher, Ceryle alcyon.
Northern Raven, Corvus corax-principalis.
Flicker, Colaptes amatus.
Bald Eagle, Haliætus leucocephalus.
Song Sparrow, Melospiza fasciata.
Redpoll, Acanthis linaria.
Cedar Waxwing, Ampelis cedrorum.
Great Horned Owl, Bubo Virginianus.
American Goshawk, Accipiter atricapillus.
Brown Creeper, Certhia familiaris Americana.
Loon, Urinator imber.
White Crane, Grus Americana.
Blue-headed Vireo, Vireo solitarius.
Hudsonian Chickadee, Parus Hudsonicus.
Oven-bird, Seiurus aurocapillus.
American goldfinch, Spinus tristis.
Hermit Thrush, Turdus aonalaschhæ pallasii.
Ptarmigan, Lagopus lagopus.
Ruffed Grouse, Bonasa umbellus.
Canada Grouse, Dendragapus Canadensis.
Golden-crested Kinglet, Regulus satrapa.
Pileated Woodpecker, Ceophlœus pileatus.

The ornithologist will be interested to learn that the prairie hen was found in the region. Only one flock, however, was seen. Several ptarmigan were also observed.

V. CONCLUSION

That this region will be a valuable addition to Ontario's agricultural lands cannot be doubted. It resembles the Temiskaming district in many respects, and the progress of agriculture in this district is a guarantee of the agricultural value of the region under consideration. Its vast extent of clay and clay loam soil, the richest and best-drained being the twenty-five per cent. of the region wooded with aspen, poplar and associated trees; its supply of pulpwood, which will aid the settler in making the "early" years profitable; its spruce, poplar, balm of Gilead and birch, which will provide a considerable amount of timber for export after the needs of the settler are supplied; its jack-pine and tamarack, which will provide material for railway ties; its stores of peat, which, on the development of the peat industry, will afford a valuable supply of fuel; its numerous rivers and streams, which naturally irrigate the country and, as well, afford drainage; its deposits of sand and gravel, and its outcrops of rock, which will be useful for building purposes, and the making of roads; these are some of the factors which will aid in the development of this region as soon as it is brought into connection with southern Ontario, and the rest of Canada by railway construction.

VI. APPENDIX

(1). Chemical Analyses of Soil

The following report on the chemical analysis of the soil samples collected by the writer was made by Prof. Harcourt of the Ontario Agricultural College, Guelph.

"During the last excursion of the Provincial Bureau of Mines Exploration Party into the Abitibi, Mr. A Henderson, B.A., Agriculturist of the party, collected a number of samples of soils typical of the sections passed through. As we could not undertake to analyse all the soils collected, Mr. Henderson selected seven samples, each of which had been gathered in such a way as to fairly well represent the soil characteristic of as many different sections of the country, and submitted these for analysis.

"The following notes on the location and the trees growing on the soil from which the samples were taken were made by Mr. Henderson:

"*No. 5.* From Frederick House river bank at the north boundary of Mann township. Timber—spruce 6 to 8 inches, birch 5 to 6 inches, and poplar 10 inches in diameter, growing about 40 feet high.

"No. 9. From Teefy township. Characteristic soil of the Abitibi river bank, extending from one-quarter to two miles back from river. Heavily timbered, poplar, spruce, balsam, and occasional birch and jack pine, trees large. There is a well decayed covering of humus six inches deep.

"*No. 11.* From Knox township, jack pine soil. Principal trees jack pine, poplar, black spruce, and a few birch, rather small. Very little decaying organic matter on surface.

"*No. 17.* From Teefy township, at Iroquois falls. One of the most common soils in the Abitibi district—a representative soil—along with No. 9 of the river bank and poplar knoll areas of the region traversed. Timber is poplar, spruce and balsam. Poplar grows very large.

"*No. 23.* From bank of creek flowing into Frederick House river near the point where it crosses Niven's line (mile 157). Timbered with spruce, poplar, and balsam, 8 to 15 inches in diameter. Scattered timber, much wind fall. Cedar 12 inches in diameter along water edge.

"*No. 30.* From bank of creek in Knox township. A common soil along creeks and rivers. Luxuriant growth of river hay, willows, alders, etc. Apparently the most productive soil in the Abitibi district.

"*No. 29.* From a tamarack swamp, with a growth of large tamarack (now all dead), and a dense undergrowth of alder shrubs. Sample taken from the top of subsoil, covered by one foot of decaying organic matter. This soil is like that of the black spruce forest, which covers 59 per cent. of the region traversed.

"The following table gives the composition of the soils. The samples were taken below the layer of decaying organic matter, and may, therefore, be considered subsoils.

(2). Composition of Soils from Abitibi District

Constituent.	No. 5.	No. 9.	No. 11.	No. 17.	No. 23.	No. 30.	No. 29.
Moisture	1.4	3.4	0.72	4.30	3.91	5.29	5.15
Organic and volatile	3.9	13.55	3.64	14.33	7.36	18.24	14.27
Insoluble residue	86.3	67.3	68.7	64.8	68.1	54.8	60.81
Iron and aluminium (Fe_2O_3 and Al_2O_3)	6.52	9.23	4.3	12.15	14.45	11.81	13.55
Lime (CaO)	0.795	1.615	0.91	1.285	1.08	1.81	1.58
Magnesia (MgO)	0.51	0.482	0.767	1.34	2.26	0.604	4.41
Potash (K_2O)	0.25	0.75	0.118	0.74	0.864	0.96	0.8977
Phosphoric acid (P_2O_5)	0.115	0.17	Trace.	0.143	0.105	0.238	.24
Total nitrogen	0.087	0.387	0.07	0.297	0.12	0.512	.157
Humus	1.28	6.98	0.90	5.05	1.07	6.42	8.21

"The above table of analysis does not give definite information regarding the form of combination of the various plant food constituents, nor does it tell how much of the potash and phosphoric acid are in an available form; but it does show plainly which soils have enough plant food to rank as good productive soils, provided the physical conditions are right.

"Soil No. 11 is almost totally unfit for agricultural purposes, and No. 5 is hardly up to the minimum limits for good crop production. Fortunately these soils form a comparatively small part of the Abitibi district, and should never be cleared up, but should be kept as forest reserves.

"According to the figures in the table Soil No. 30 should, other conditions being equal, give the best results when it is put under cultivation. This agrees with Mr Henderson's notes, for he pronounces this the most productive soil in the whole Abitibi district.

"The most important point in connection with these analyses is, however, the fact that soils Nos. 9 and 17, which Mr. Henderson states are the representative soils of the poplar knoll and river bank types of country (25 per cent. of the area explored), are well supplied with lime, potash, phosphoric acid and nitrogen. They are a little low in phosphoric acid, but it must be remembered these samples were taken below the top black mould, and are, therefore, more likely to be poor in this constituent.

"No. 29, representative of the black spruce forest type of country (59 per cent. of the area explored), is a fair soil. The amount of phosphoric acid is somewhat low but potash is very high. This subsoil contained more humus than any of the other soils we have examined, although apparently is was not very well decomposed, because the amount of nitrogen is low. I am of the opinion that this soil would, with judicious treatment, be quite productive.

"It is very doubtful if any of the ordinary soils of older Ontario ever contained any larger amount of the mineral constituents, and there is no apparent reason why these should not be good productive soils."

(2.) Physical Analyses of Soils by Prof. Reynolds, O. A. College, Guelph.

No.	Locality.	Grade.	Sand group.	Clay group.	Coarse gravel.	Org. matter.	Sand group: Fine gravel.	Sand group: Coarse sand.	Sand group: Med. sand.	Sand group: Fine sand.	Sand group: Very fine sand.	Clay group: Silt.	Clay group: Clay.	——
1	From west boundary of Third Township N. of Prosser, spruce forest	Clay	21.22	78.78	1.50	9.00	0.88	2.13	2.83	9.61	6.07	24.30	54.48	Good strong soil, rich in org. matter.
2	N.W. cor. of Third Township N. of Prosser, poplar knoll	Clay loam	27.60	72.40	1.01	3.90	1.53	2.32	3.64	14.05	6.05	43.39	29.02	" " low "
3	From N. boundary of Warden Tp., poplar and birch.	Sand	95.42	4.58	0.12	0.54	2.29	22.00	39.85	30.33	0.95	1.69	2.89	Not much use.
4	From Frederick House river bank at Nieland's Rapids	Sandy loam	61.78	38.22	0.00	3.60	0.00	0.10	0.36	15.09	46.23	22.32	15.90	Light, workable soil, low "
5	" " " at N. boundary Mann Tp	Loam	53.15	46.85	2.17	3.90	0.00	0.18	0.81	23.26	28.90	23.30	23.55	Good loamy soil, " "
6	Couchiching Falls Portage, spruce, poplar and birch.	Sandy loam (gr.)	67.20	32.80	13.75	8.04	8.07	12.68	14.51	23.39	8.56	24.74	8.05	Light and gravelly, but rich "
7	From Frederick House river bank where it crosses Niven's line	Clay	12.00	88.00	0.40	3.00	0.56	1.19	0.81	2.58	6.85	24.40	63.61	Strong clay, low "
8	From N. boundary of Third Tp. W. of Tully Tp. heavy birch, spruce, poplar	Loam	60.24	39.76	0.00	4.98	0.00	0.00	0.00	20.40	39.84	31.30	8.46	Fairly good loam, medium "
9	From Teefy Tp., characteristic soil of Abitibi river bank	Clay	13.20	86.80	0.00	10.12	0.36	2.25	2.91	3.79	3.86	29.89	56.94	Strong clay, rich "
10	From township W. of Mann, poplar knoll	Clay loam	34.25	65.75	0.85	1.82	0.72	1.88	0.79	15.82	15.54	42.15	23.60	Medium clay loam, poor "
11	From Knox Township	Clay	12.10	87.90	0.00	0.55	0.76	1.22	0.98	5.20	3.95	53.40	34.49	Strong clay, " "
12	From the extensive brulé of Mann Tp., spruce forest.	Clay	13.94	86.06	0.30	6.40	0.35	1.89	3.94	3.79	3.97	36.01	50.05	" medium "
13	From a depression 3 chains wide between two rock ridges Knox Tp	Clay loam	35.72	64.28	0.82	6.66	1.35	3.07	5.12	22.91	3.27	20.14	44.14	Medium clay loam " "
14	From Calvert Tp., poplar knoll	Loam	56.89	43.11	0.22	4.00	0.66	2.00	2.08	20.42	31.73	28.48	14.63	Light loam " "
15	From N. boundary of Warden Tp., jack pine area	Sand	89.64	10.36	0.00	2.20	2.78	28.18	32.37	23.58	2.73	4.40	5.96	Not much use.
16	From Second Tp. W. of Mann, poplar knoll	Clay	17.05	82.95	4.20	2.62	0.87	1.79	1.47	7.62	5.30	47.37	35.58	Strong clay poor "
17	Teefy Tp. at Iroquois Falls (a common soil in clay belt)	Heavy clay	7.08	92.92	0.00	10.00	0.00	0.30	0.20	3.17	3.41	22.44	70.48	Very heavy rich "
18	From Prosser Tp., poplar knoll, another common soil	Loam	47.44	52.56	20.81	10.00	9.04	11.14	7.31	12.45	7.50	27.09	25.47	Good medium loam " "
19	From Rickard Tp., Abitibi River bank	Clay loom	27.85	72.15	0.10	2.32	3.08	3.11	2.12	6.95	12.59	34.62	37.53	Good clay loam poor "
20	From Edwards Tp. (a common soil) poplar knoll	Heavy clay	10.85	89.15	0.00	6.58	0.32	0.92	1.33	4.51	3.77	31.98	57.17	Very heavy medium "
21	From Abitibi river bank at Buckdeer Rapids	Sandy loam	65.86	34.14	0.00	2.77	0.00	0.16	2.11	48.77	14.82	12.88	21.26	Light poor "
22	From W. boundary Prosser Tp., poplar knoll	Clay loam	26.21	73.79	2.63	6.92	2.05	3.69	4.13	11.44	4.90	37.12	36.67	Strong clay loam, medium "
23	From bank of creek flowing into Frederick House river, near Niven's Line	Clay to heavy clay	11.36	88.64	0.00	5.82	0.86	1.76	1.90	1.92	4.91	31.25	57.40	Very heavy " "
24	From Edwards Tp., spruce and poplar	Clay to heavy clay	10.70	89.30	0.00	10.00	0.08	0.41	0.68	5.44	4.09	12.12	77.18	" rich "
25	From high, sloping bank of small lake in Tp. W. of Tully	Loam	44.95	55.05	3.44	1.60	1.45	3.80	7.80	22.40	9.50	17.70	37.35	Medium loam poor "
26	From Calvert Tp., poplar knoll	Loam	39.62	60.38	0.00	6.76	2.31	8.72	8.19	13.27	7.13	4.32	56.06	" medium "
27	A typical tamarack swamp		*	......	......	......	......	......	......	......	......	......	......	......
28	From same bank as sample 5, 10 lower down, 10 feet nearer river level	Clay	22.91	77.09	0.74	3.68	0.55	1.80	2.18	4.94	4.42	31.60	45.49	Medium clay, low in org. matter
29	Tamarack swamp, subsoil N. Abitfbi River, opposite mouth of Dokis		......	......	......	......	......	......	......	......	......	......	......	Whole sample taken by Chemical Department.
30	From bank of creek in Knox Tp. (most productive soil in Abitibi country)	Clay	23.55	76.45	0.00	12.35	2.34	6.87	3.08	4.76	6.50	35.87	40.58	Medium clay, very rich in org. matter
31	Peat sample	Nearly all humus.	......	......	......	92.47	......	......	......	......	......	......	......	......
32	From Little Tp., jack pine, plain soil	Light sandy loam.	89.69	10.31	3.58	1.50	10.59	33.94	32.08	11.21	1.87	5.72	4.59	Not much use.
33	A common soil, spruce and birch	Clay	18.49	81.51	0.00	7.42	0.63	3.85	3.46	6.49	3.06	34.46	47.05	Strong clay, rich in org. matter
34	From bank of small lake on N. boundary, Third Tp. W., poplar knoll	Clay loam	39.10	60.90	0.53	2.20	1.62	2.78	3.64	15.12	15.95	42.45	18.44	Medium clay loam, poor "

35 From N. bank of Porcupine R. in Gowan Tp.	Clay loam	31.10	68.90	0.00	9.06	1.07	2.02	1.76	8.09	18.16	53.55	15.34	Medium clay loam, rich in org. matter	
36 From Wesley Tp., black spruce forest subsoil, 14 inches mould above	Heavy clay	2.89	97.11	0.00	6.07	0.00	0.00	0.33	1.75	0.81	15.44	81.67	Very heavy	medinm "
37 Black spruce forest subsoil	Clay	17.27	82.73	0.00	9.45	0.59	1.97	2.23	7.82	4.66	28.33	54.40	Strong clay	rich "
38 From Mann Tp., black spruce forest subsoil under 18 inches mould	Clay	17.40	82.60	0.01	7.43	1.83	2.25	1.60	4.78	6.94	39.18	43.42	"	" "
39 From Abitibi R. bank	Clay loam	32.25	67.75	0.00	5.85	2.45	10.32	6.61	8.58	3.99	10.10	57.65	Medium clay loam,	medium "
40 From Nieland's Rapids, Frederick House river bank.	Clay	21.20	78.80	0.00	8.72	0.18	2.10	1.76	3.10	14.05	38.66	40.14	Medium clay	rich "
41 From Rickard Tp., jack pine plain	Light sandy loam	77.54	22.46	0.13	3.70	0.00	2.44	14.08	55.32	5.71	7.02	15.44	Very light	low "
42 From Second Tp. N. of Tully, poplar knoll	Clay	12.66	87.34	0.00	1.82	0.32	1.47	1.96	4.79	4.12	32.05	55.30	Very heavy	poor "

* Incapable o definite analysis on account of humic acids.

Of samples sent 5 per cent. were heavy clay ; 39 per cent. of clay 19 per cent. o clay loam ; 15 per cent. of loam 7 pe cent. of sandy loam ; 5 per cent. of light sandy loam ; 5 per cent. of sand ; 5 per cent. of swampy.

N B.—Particles in the samples that are too large to pass through a two millimetre sieve are known as coarse gravel. The dividing line between the clay and silt group on the one hand, and the sand group on the other, is one five-hundredths of an inch for size of particles.

McCANN TOWNSHIP AND N. W. OF LAKE ABITIBI

BY J K WORKMAN

[The following notes descriptive of the township of McCann, which lies west of the Temiskaming and Northern Ontario railway and north of the Height of Land, and also of the country adjacent to the base line run by O. L. S. Speight in 1904 eastward from the 162nd mile post on the boundary between the districts of Nipissing and Algoma, are by Dr. J. K. Workman, who accompanied Mr. Speight's survey party in the capacity of geologist. Like much of the region in the neighborhood of lake Abitibi, the soil and timber are likely to prove of more importance than possible resources in the way of minerals; and observations of the geology are difficult and scanty owing to the widespread mantle of drift material which effectually conceals the rock formations. T. W. G.]

About the middle of May 1904, I received instructions from Mr. T. W. Gibson, Director of the Bureau of Mines, advising me of my appointment as geologist attached to the surveying party of Mr. T. B. Speight, O. L. S., who would be engaged during the summer in running base lines in the district lying northwest of the Abitibi lakes.

My instructions were to gain all the information possible about the rocks and minerals occurring in the districts immediately adjacent to Mr. Speight's lines, but if it so happened that the district was covered with drift and therefore an agricultural section, I was to devote my time to studying the character of the soil and timber. It was also my duty to note the flora and fauna encountered during the summer.

Mr. Speight notified me that the party would leave Toronto on Friday, 26th May. Deciding to join him there I left Kingston on Thursday and so was enabled to have an interview with Mr. Gibson, receiving more detailed instruction and some instruments for use during the trip. Mr. Speight's party did not leave on Friday, as planned, on account of the heavy rainfalls earlier in the week; however they arrived at New Liskeard on Tuesday's boat. We left next morning via steamer Geisha but had to transfer at the mouth of the Blanche river to the steamer Ville Marie, as we met with an obstruction of logs at this point. We arrived at Tomstown during the course of the afternoon.

On the morning of 2nd June all arrangements having been completed, we left on our trip northward in five Peterborough canoes. There were seventeen men in the party, all told. We made good time going in. Ascending the Blanche river we passed through Round and Kenogami lakes, then continuing up Black creek, which is very sinuous, we came to the Height of Land portage. Crossing this, we descended the White Clay and Black rivers to McDougall's clearing, arriving at this point on Friday 9th June, having met with no serious accident or delay. Here we cached most of our provisions, and next day we started south on a canoe route which leaves the Black river at this point for Metachewan post, as Mr. Speight intended to finish subdividing McCann township before commencing his base line work. The series of lakes and portages at this end of the canoe route has already been described by Dr Kay in the Thirteenth Report of the Bureau of Mines.

McCann Township

The topography of McCann township is somewhat diversified. In the northern part the elevation does not vary much. In the central portion west of Grave lake, and east and west of Bethea lake there are a number of ridges which have a general direction of northwest and southeast. Some of these ridges attain an elevation of one hundred and fifty feet or more above the level of the lakes. In the southwest part of the township the ridges do not attain as great elevations, nor do they seem to have any common direction. They are flanked by long easy slopes of sandy soil.

The lakes in the township are six in number. The north boundary of the township cuts across Cherty lake about ten chains from its southern extremity. Grave, Bethea and Gowan lakes have been described by Dr. Kay. Cayea lake lies about three-quarters of a mile east of Bethea lake. It is about fifty chains long and fifteen wide, its longer

axis lying north and south. The sixth lake is about the same size as Cayea lake, but with its longer axis lying east and west. It is situated in lots 9 and 10, concessions I and II. These lakes were all traversed by Mr. Speight while surveying the township, and so can be accurately placed on the map. We found them very useful as they facilitated the work of moving camp to various positions in the township.

ROCK EXPOSURES

There are only a few rock exposures in the township. These are, with one exception, phases of the dolerite described by Dr. Kay; this exception occurred on the top of a ridge one hundred feet high, three-quarters of a mile west of Grave lake. Here the roots of a fallen tree had torn away the soil and laid bare a contact of medium-grained dark dolerite and a light colored granite, the dolerite being superimposed on the granite. The dolerite lay to the south, the line of contact being about east and west. Although a careful search was made no further exposure was seen in this neighborhood.

Four other exposures, all of dolerite, occur in the township: (1) near the west boundary, lot 12, con. II. Here there is a low ridge-like exposure of coarse dolerite, which runs north and south, but soon becomes lost in the glacial drift. (2) On the southwest shore of Bethea lake there is a small exposure of medium-grained dolerite carrying a considerable amount of pyrite. A similar outcrop occurs just across the lake in a northeasterly direction. (3) By far the largest mass of rock exposed in the township is situated east of Bethea lake. It is a ridge-like formation over one hundred and fifty feet high, and about a mile in length, having a general southeast and northwest direction. This rock too is doleritic in character, but has a certain degree of schistosity developed. (4) Along the east boundary from con. II to con. IV, there is a series of outcrops of a ridge of fine-grained pyritous dolerite.

SOIL

The soil of the township is also much varied in character. The northeast and central parts have a good clay soil, but parts of the north and east tracts require draining. The southwest portion has a soil of a sandy nature, but the tops of the ridges are composed of a sandy loam. The tract lying to the southeast has more clay in its composition, but it is rather low and wet, being covered with moss and small bushes. Along the east boundary it is swampy on account of the ridge of rock to the east, which holds the water.

Including the parts that need draining, about sixty per cent. of this township is suitable for agricultural purposes.

TIMBER

The timber of the township is not valuable except for pulp-wood and building purposes, with the exception of the cedar, which grows in the swampy section on the east side. The sandy tracts in the southwest part of the township are sparsely wooded with small Banksian pine. The ridges and the rest of the township are covered with spruce, balsam, white birch and poplar. A few isolated pines and soft maples were also noted. There is quite sufficient timber to meet all agricultural purposes.

On Thursday, 8th July, we finished the township, and the next day we returned to McDougall's clearing. Saturday Mr. Stock, who had been with the party locating veteran's claims, and three of the men started for New Liskeard by the Blanche route. The rest of the party continued down the Black river. For the first five miles the east bank showed evidence of having been burnt over years ago, but the river passes through a good clay area, which seems to be very suitable for agricultural purposes.

Before we reached the Abitibi river we met some other members of the party, who had been away bringing in supplies by the Quinze route, and were on their way to join

us. This part of the Black river and the Abitibi river to the Long Sault rapids has already been thoroughly described in Reports of the Bureau of Mines, namely, by Dr. Parks in the Eighth Report, and by Dr. Kay in the Thirteenth Report; also by Mr. M. B. Baker in the Report of the Exploration and Survey of Northern Ontario in 1900, and by Mr. W. J. Wilson in the Summary Report of the Geological Survey, 1902.

If the soil we saw in passing down the rivers is typical of the district, this will undoubtedly be a very fine agricultural section when the railways are completed and is is opened up and settled.

Work on Base Line

On Monday 11th July we arrived at an Indian's shack on the right bank of the river. Mr. Speight had decided to make this point his base of supplies during the commencement of the base line work. Here we found that the men who had gone ahead of us to cut out a trail from the 162nd mile post on the Nipissing-Algoma boundary to the Abitibi river, had not yet returned.

In order to accomplish something during this enforced delay, Mr. Speight decided to move part of the provisions to another shack at the head of the Long Sault. This was the undertaking in which we were so unfortunate as to lose two men by drowning. Meanwhile we had moved five miles down the river to the point from which the guides had started on their trip to the boundary. As they had not returned by Friday, we commenced our journey to the line by this route. This trail came out at the 166th mile post, so we had to go four miles south to the starting point of the base line work.

Commencing at the river, the first three-quarters of a mile of this trail passed through a wet swampy tract covered with moss, and in places Labrador tea, the timber being entirely spruce. Then we came to the only exposure of rock met with west of the Abitibi, a small outcrop of light-colored, coarse-grained granite. Passing over a slight rise at a distance of one mile from the Abitibi, we came to a river forty feet wide, flowing northward, but it was unnavigable owing to driftwood. Crossing the river we continued in a southwest direction. The soil in this vicinity was a very fine clay, supporting a growth of large timber, mainly spruce, while birch, tamarack, poplar and balm of Gilead.

At a distance of five miles from the Abitibi river we came to a lake one mile long and twenty chains wide, its longer axis being north and south. We continued around the north end of this lake, crossing the outlet, a river forty feet wide. A little further on we crossed a second stream twenty-five feet wide which flowed south and entered the lake.

In the next three miles the ground became higher; the timber however was the same as that east of the lake. Another mile brought us to the line; this last tract was somewhat swampy and covered with moss. The timber, which was all spruce, would average ten inches. The line to the 162nd mile post was of the same character as this last mile of the trail.

On Tuesday 19th July the base line work proper was commenced. The ground was fairly level and covered with moss to a depth of six to twelve inches. The timber was spruce and balsam. At five miles and thirty chains, a river half a chain wide flowing northward, was crossed. East of the river the ground became much higher, and we entered a belt of poplar about a mile wide, and extending for several miles both north and south. The seventh and eighth miles passed through a tract much lower in elevation, and consequently wet and mossy, the poplar giving place to spruce and balsam. We now passed over a low ridge, and the ground again became marshy. This condition prevailed until within a short distance of the river, when we came to another ridge wooded with spruce, poplar, white birch and balm of Gilead. At nine miles and fifty chains the river was crossed, about one-quarter of a mile north of the shack at which we had left our first cache.

EXPLORING UNDER DIFFICULTIES

Monday 25th July five men quit work and left for New Liskeard. We moved camp out to the 12th mile post, and on Tuesday Mr. Speight sent two men out to the Hudson Bay Company's post, lake Abitibi, to try to secure more men. This left him very short-handed to go on with the work; in fact for two weeks the party consisted of eight men all told.

East of the Abitibi river the soil is much drier, and the timber, which is spruce, balm of Gilead, balsam and poplar, averages ten inches for the first two miles. Near the 12th mile post we enter a belt of poplar about one-half a mile wide. The timber to the 14th mile post is spruce and balsam. Just before the 14th mile post is reached we come to the Sucker river, which is about twenty-five feet wide, and flows north at this point. The land on both sides of the line from the 14th to the 17th mile post is much higher, and supports a growth of spruce, white birch, balsam, and some poplar.

In the 18th mile this timber gives place to rather small sized spruce. About half a mile to the north there is a small creek, which crosses the line at the 18th mile post. It flows in a westerly direction, and joins the Sucker river. Years ago this creek had been used by beavers, but now the valley is filled up with a growth of black alders and willow. In the 19th mile the timber is much larger, averaging twelve inches, but there is a considerable amount of down timber, making travelling difficult. The line in the 20th mile passes through an open country, which stretches several miles both north and south, and is sparsely wooded with bastard spruce. The remaining three miles of this line is rougher, the timber being mainly spruce, and comes under the classification brulé. This tract extends to the Sucker river on the west, to the 5th mile post on the north, and several miles to the eastward.

Continuing, we now enter a more open section, wooded with spruce and balsam, which average five inches. In the seventh mile the timber is much larger, and consists of spruce, tamarack, white birch and balsam. Adjacent to the ninth mile the ground is covered with a greater depth of moss, and is wet and soggy. This condition prevails to the 12th mile post, except that the timber is much larger in the latter vicinity. In the thirteenth mile the soil becomes much drier. Just west of the 13th mile post is a small lake. This is the first met with east of the Abitibi river. The timber to the 16th mile post is spruce, balsam, poplar and birch, averaging twelve inches.

THE CHIN RIVER

At this point the Chin river is reached, two and a half chains wide, with banks thirty-five feet high. We crossed over on a raft without serious mishap, and camped on the north bank. The timber north of the river is large, spruce, tamarack, birch, balsam, balm of Gilead and poplar, with a considerable amount of windfall.

This part of the Chin river is made use of in the canoe route from the head of the Long Sault to Little Abitibi lake. On Saturday, 20th August, some of the guides reached the camp, bringing in provisions from our cache at the head of the Long Sault, in a birch canoe. I made use of this canoe to make a short exploratory trip up the river. Soon after starting we passed some sharp angular boulders of gneiss in the bed of the stream, their tops being two or three feet above the surface of the water. The river gradually turns to the northeast, and after travelling two miles our course lay due north, then northeast for thirty chains. A short bend to the right brought us to a lake which lay to the north of the river, its longer axis, one-half mile in length, being parallel to the river, *i.e.*, northeast. Continuing up to river thirty chains northward we came to a second expansion or lake, a little over half a mile long and thirty chains wide, its longer axis lying northwest and southeast. The river enters this lake in the southeast corner. We continued eastward up the river; about twenty-five chains from the lake we came to a shack on the north bank, which belonged also to the Indian whose huts we made use of on the Abitibi river. Half a mile above this shack we pitched camp for the night. The next day it rained, but we ascended

the river two miles farther in a southeasterly direction, and came to an extended jam of driftwood. As there was no portage to avoid this, we turned back. Arriving at the northern lake we skirted the shore looking for the portage leading to Little Abitibi lake. In this quest we were unsuccessful.

From the northwest corner of the lake we cut across to the line, arriving at the nineteenth mile post, the distance being three-quarters of a mile. Returning to the canoe, we took it back to where the line crossed the river and camped for the night. In the meantime Mr. Speight had moved to the head of the line, so next day we caught up to him. The timber from the river to the end of this twenty-four miles is large, and similar to that found south of the river. Small lakes are not infrequent in this section.

On Wednesday 24th August the line being finished, we retraced our steps to the 12th mile post and turned on to the base line running west from this point. The first mile was swampy, but in the second the ground became higher. At the second mile post we came to the Chin river again, which here was flowing southwest. Crossing this another half mile brought us once more to the river, now flowing northwest, it having made a long bend. The banks at this point were very high, about forty feet.

The canoe being available for a short trip, I went down the river about three miles. The river had a general northwesterly direction. Ten chains from the line a small mass of gray granite was observed on the west bank. Half a mile down just below two small riffles we came to an outcrop of coarse banded gneiss.

Thirty chains farther on brought us to a low outcrop of granite, making a small bay where the river swerves to the right. A mile and a quarter down there is an exposure of pink gneiss, with a face about twenty feet square, standing out from the river bank.

The banks now become lower, being about five feet high. The timber is good sized spruce, tamarack and balsam. After going three miles we turned back. Going south from the line we arrived at the junction of the Chin and Sucker rivers, about a quarter of a mile up. Turning into the Sucker we passed a portage about twelve chains up, which leads to the head of the Long Sault, taking advantage of a couple of lakes.

A mile up the Sucker we came to a fifteen-chain portage on the left bank, to avoid a series of small rapids.

The river up to this time had a northeasterly course; above a bend its direction was southwest. We turned into a small creek lined with alders. At first our course was south, but gradually turned to the west.

Two miles and a half up this creek brought us to the end of the first portage from the Sault. Here I observed a small group of scrubby Banksian pine. At no other point were any of these trees seen after entering the Abitibi district.

Leaving the canoe here we struck off north across country reaching the line in about two miles. From this point to the Abitibi river, a distance of six and one-half miles, the ground is lightly rolling in character. The timber is medium sized spruce, birch, balsam and poplar. Two small lakes are passed, the water from each flowing northward. At ten miles and forty chains the Abitibi river is reached, about four miles below the head of the Long Sault. After having finished the remaining mile and a quarter of line, tying in on the 174th mile post of the Nipissing-Algoma boundary, the packers said they were unable to bring provisions down the rapids. As the rest of our base line work was below the Sault, Mr. Speight decided to discontinue operations for the summer.

On Thursday 1st September we started on our homeward trip. Along the banks of the Long Sault, there are a great many exposures of gneiss, and gneissoid and granite boulders occupy the stream and shore.

We returned via the Abitibi lakes and Quinze route, reaching New Liskeard on 9th September.

SOIL OF BASE LINE REGION

The soil along the base line work was all of the same character. With one exception is found in wet spongy places, where a brown muck overlies the clay. In exception it consists of a heavy clay, and would be excellent for wheat growing. The spots it is over seven feet in depth.

In my opinion it is very important that the vegetable mould on the surface of the ground should be worked into the soil, instead of being burnt off when clearing. As the roots of the trees in this district are not deep-seated, this result could be accomplished by using a stump-drawing machine, and burning everything in one place.

CLIMATE

The climate of this district, while now a temperate one, will become milder as it is cleared. No severe frosts were experienced while we were in the field.

There is a scarcity of boulders. A number of gneiss and granite boulders gathered together at one of the Indian shacks where they are used in the manufacture of canoes, presented an unusual sight.

INDIAN OCCUPATION

The Indians all have shacks on these hunting grounds, but they only occupy them during the winter, when they are engaged in hunting and trapping. During the summer months they camp near the Hudson Bay Company's post doing nothing. McDougall on the Black river had a few acres of potatoes, but none of the other Indians had made any attempt to grow any vegetables.

FAUNA

Moose and red deer are plentiful in the neighborhood of the Height of Land. In McCann township we saw several moose, but no red deer. While on the base line work we only saw four moose, but their tracks were plentiful in places. Cariboo are very scarce, according to the Indians. We did not see any all summer. Only three black bears were actually seen, but tracks and fresh work were noted almost everywhere. This was particularly evident on the journey out. The soft clay borders of both banks of the Abitibi river, left dry by the low water, had been tramped over for miles by bears in their search for berries.

Beaver trails and work were noted along the base lines, but these intelligent little animals are scarce in this district.

No porcupines or skunks were seen, but one ground-hog was trapped by the guides.

Rabbits were not plentiful this year.

Partridges are not abundant, but may be found almost anywhere. Black, red-headed and wood duck were observed in Abitibi river.

Other birds noted were the Canada bird, woodpeckers, cedar bird, canaries and warblers, sandpipers and plover, least bittern, owls and ravens. One lizard and three garter snakes were seen in McCann township.

FLORA

Sedum latifolium or Labrador tea was very common. Yellow water lilies and pitcher plants were abundant. Two varieties of ladies' slipper were numerous, viz,, Cypredium parviflorum and C. creaule. Members of compositae family were common, *e.g.*, daisies, flea-bane, bur marigold, goldenrod, Canada thistle, dandelion, etc. Other flowers noticed were the cardinal lobelia, tuentalis or star flower, sweet briar, and wild roses, blue flags and spotted lilies. Berries were not plentiful, but we found the following varieties: strawberries, raspberries, two varieties of gooseberries, June berries, two kinds of red currants, huckleberries and high bush cranberries.

FISH

We did not catch many fish, but nearly all the lakes contain pike and pickerel. The Abitibi river is almost too muddy for fish to see to take a bait. We only caught a few taulibi and perch in it.

LOON LAKE IRON-BEARING DISTRICT

BY W N SMITH

Within the past year considerable activity has been shown in exploration for iron ore in the Animikie iron-bearing series near Loon Lake, about 26 miles east of Port Arthur. Besides the natural stimulus to exploratory work resulting from the discovery of areas which show considerable concentration of ore, the bounty which the Ontario government offers for domestic ore and the import duty recently imposed by the Dominion parliament upon foreign steel, have given impetus to Canadian prospecting. During the latter part of the summer of 1904 the writer was associated in a somewhat detailed mapping of the Loon lake area, and the following notes are based on observations then made.

The principal exploratory work in the area in question has been done by Mr. Rinaldo McConnell, of Ottawa; Messrs. Knobel and Flaherty, of Port Arthur, and Messrs. Wiley Bros. and Marks, also of Port Arthur, and to these gentlemen the writer is indebted for the fullest opportunity for examining the properties controlled by them, as well as for many personal courtesies. The exploratory work has consisted mainly of diamond drilling and test-pitting. The formations are magnetic only locally where intruded by igneous rocks, and therefore magnetic surveys are not of assistance in locating the areas of concentration.

The location of the area in reference to transportation is exceptionally favorable. The Canadian Pacific railway passes through the district and thus offers a short haul to that company's docks at Port Arthur, and the waters of Thunder bay of lake Superior are but four miles south of Loon lake. From Loon lake to Thunder bay is a descent of 400 feet.

A MESABI EXTENSION

The Animikie iron-bearing series, in which the ore of this area occurs, is the eastward continuation of the Mesabi or Upper Huronian series of Minnesota. Its connection with the Mesabi series has been recognized for many years. The Animikie series first came into commercial prominence some 40 years ago as a result of exploration in it for silver and iron ores, and the considerable production of the former metal.[1] The early explorations for iron, however, were not attended with success, and in recent years comparatively little systematic prospecting for this ore has been done.

GENERAL GEOLOGY

With the exception of the Pleistocene drift, the rocks of the area, so far as can be determined, are all of pre-Cambrian age. The succession is as follows:

Pleistocene .... Glacial drift.
(Unconformity).

Keweenawan (Nipigon). .... Conglomerate, sandstone, marl, diabase sills.
(Unconformity).

Upper Huronian (Animikie)........... Iron-bearing formation and black slates.
(Unconformity).

Lower Huronian...................... Graywacké, greenstone, granite.
(Unconformity).

Keewatin .... Green schists, greenstone, mashed porphyries.

[1] Report on Mines and Mining on Lake Superior, by E. D. Ingall. Ann. Rept. Geol. & Nat. Hist. Surv. of Canada (new ser.), Vol. III, Part II, 1887-8, Report H.

A summary of the general geology may be given before taking up the iron-bearing horizons.

The Archean rocks are not exposed near Loon lake, but along the Canadian Pacific railway, about 17 miles west of Loon lake, and extending thence in a westerly direction, is a series of greenstones, green schists and mashed porphyries, which lie unconformably below the Lower Huronian graywacké, and which are therefore regarded as belonging to the Keewatin. The general strike of these rocks is east-west, and the dip approximately vertical.

THE SCHISTOSE GRAYWACKÉ

The basal member of the Lower Huronian is schistose graywacké, which, from structural and lithological similarity, is correlated with the Knife lake graywacké-slate formation of Lower Huronian age of the Vermilion district of Minnesota. The general strike of the schistosity is about north 80 degrees east; with which direction the trend of the graywacké ridges conforms. The dip of the schistosity varies from about 65 degrees south to 65 to 70 degrees north. The strike and dip of the true bedding are frequently discordant with the strike and dip of the schistosity. Where igneous intrusion was most intense, and where, perhaps dynamic movement was more severe, the graywacké has been altered to hornblende-schist. In general the graywacké is a medium-grained typical graywacké, but locally it possesses true quartzite phases on the one hand and slaty phases on the other.

Also interbedded with the graywacké near what is believed to be its base, is a considerable thickness of volcanic material, represented by volcanic conglomerates, finely banded tuffs, and amygdaloids. This is best exposed at about the centre of the area east and west between Lambert island and the Canadian Pacific railway.

The most western exposure of the graywacké series is largely represented by a schistose conglomerate containing pebbles of the various phases of the underlying Keewatin, together with fragments of a massive granite and porphyry. The granite pebbles are probably derived from the Laurentian granites, which although not exposed in the area mapped, occur over a considerable area north of Port Arthur. Probably the most persistent pebbles in this conglomerate are vein quartz and black jasper, the latter being derived from the magnetic iron formation which is associated with the Keewatin greenstones and schists of this region. As the contact between the graywacké and the Keewatin is approached, the conglomerate character of the former disappears, and the lowest member of the graywacké very closely resembles the Keewatin greenstones. It, however, can be distinguished from them by the presence of scattered fragmental grains, and by the absence, in the graywacké series, of the minute crumpling at right angles to the general schistosity which is characteristic of the adjacent Keewatin.

GREENSTONE AND GRANITE

Throughout the area the graywacké is intruded by greenstone, also of Lower Huronian age. This greenstone occurs in masses of varying size, but with a general schistose structure parallel to that of the graywacké. In texture it varies from a rather uniform fine-grained to a coarse, massive or porphyritic rock, the porphyritic constituents being largely hornblende. In hand specimens the predominant minerals apparent are feldspar and hornblende.

Large masses of granite cut both the graywacké and greenstone on the south, west and north. The granite is medium-grained to coarse, massive textured, with quartz, feldspar and biotite as the principal mineral constituents. Hornblende is subordinately present, and locally, in pegmatitic phases of the granite, tourmaline is abundant. The granite is nowhere found intruding the Upper Huronian or Keweenawan series, but on the contrary is overlain unconformably by them. While the Lower Huronian age of the granite is thus clear, it is much later than the graywacké-greenstone

series which it intrudes, there having been between the two an interval of time at least great enough to allow of the production of the steeply-inclined schistosity in the former, since the massive textured granite is found cutting directly across this structure. The most complex intrusion, as well as the greatest metamorphic effects of the granite, are found along the north border of the graywacké.

In the central part of the area these Lower Huronian formations form prominent topographic features which well illustrate the relation between the topography and geologic structure of the area. To the north they form a series of disconnected hills with comparatively moderate descent to the valley to the south, in which the railway is located. Continuing south, the graywacké rises abruptly as a long, high ridge, the face of which represents approximately the plane of a steep east-west fault. In contrast with this steep north face of the graywacké ridge is its uniform slope southward to Thunder Bay.

THE ANIMIKIE FORMATIONS

The Upper Huronian, or Animikie, formations are found unconformably overlying all the different members of the lower series. The unconformity is indicated mainly by structural and lithological differences. Structurally, as compared with the underlying series, the Animikie is flat-lying, the general dip to the southeast varying from five to ten degrees. Lithologically, it is distinguished by the comparatively small degree of metamorphism to which it has been subjected. At the base of the series is a rather persistent conglomeratic horizon, varying from a few inches to a foot or more in thickness, the pebbles of which are small and predominantly of vein quartz.

Between the flat-lying beds of the Animikie has occurred the intrusion of laccolithic sills of diabase, to which by subsequent erosion the very characteristic hills and ridges with vertical diabase caps owe their origin. These laccolithic sills represent parts of the great similar intrusions which are found from the Minnesota coast of lake Superior on the west to Nipigon bay on the east, and which form such striking topographic features of the north shore, as the Saw-tooth hills, McKay's mountain, Thunder cape, etc.

THE KEWEENAWAN OR NIPIGON ZONES

Unconformably above the Upper Huronian is a succession of Keweenawan conglomerates, sandstones, and impure marls, to which the term Nipigon series has been applied by the Canadian Survey. This series is most fully developed east of Loon lake. The unconformity between the Keweenawan and the underlying rocks is marked in various ways. At the base of the Keweenawan is a coarse conglomerate, containing water-worn pebbles and boulders of all the underlying rocks, among which, however, granite and iron formation material are predominant. The Keweenawan shows comparatively little metamorphism, even less than the Animikie. The strikes and dips of the Keweenawan are always more or less discordant with the strikes and dips of the underlying formations. The strongest evidence of the great time interval represented by the unconformity is, however, the fact that the Keweenawan is found successively overlying both the Animikie and Lower Huronian formations, thus showing that the entire Animikie and part of the Lower Huronian had been truncated by erosion before the Keweenawan was deposited.

As was noted by Irving,[2] the base of the Keweenawan in this area is represented by a sedimentary series rather than by the great basal igneous masses which are present in the Keweenawan areas to the west and on the south shore of lake Superior. The diabase which forms the laccolithic sills of the Animikie is also found both overlying and cutting the Keweenawan sediments.

[2] The Copper-bearing Rocks of Lake Superior, by R. D. Irving. Mon. U.S. Geol. Survey, No. 5, 1883, pp. 331-332.

The western boundary of the Keweenawan is marked by a steep escarpment which extends in a southwest direction to the head of Thunder bay, and thence along its south shore nearly to Thunder cape.

STRUCTURAL FEATURES

The main structural characteristic of the area is the general dip to the southeast, in this conforming to its geographic position as a portion of the north side of the lake Superior synclinal basin. The upper surface of the Keewatin and Lower Huronian formations shares in the general slope to the south, although as previously noted this does not apply to the bedding and schistosity of the series. The normal strike of the Animikie is to the northeast, with average dip of about seven degrees southeast. Locally, however, the series has been closely folded and the resulting strikes and dips are widely divergent from the normal. The general strike of the Keweenawan is east of north, with flat dip to the southeast, although it also locally shows the same severe folding and fracturing as the Animikie.

Faulting has been an important factor in producing the present structural and topographic features of the district. The faulting is believed to have been caused by the same general forces which produced the lake Superior basin, and was therefore of post-Keweenawan time. As the general movements which formed the lake Superior synclinal occurred, the stresses on portions of the strata were relieved by fracture and accompanying vertical displacement. Thus in this area it is believed that the major fracturing occurred along certain approximately parallel zones, and that in the vertical displacements which followed, the several fracture blocks acted as independent units, in which the north half became elevated relative to the south half, thus producing a system of "block" faults.

The greatest vertical displacement definitely determined is about 300 feet, as shown from diamond drill records and surface exposures along the east-west fault a short distance south of Loon lake.

THE ANIMIKIE IRON-BEARING FORMATION

Four definite horizons are present in the Animikie as follows: (1) a lower iron-bearing member; (2) an interbedded black slate; (3) an upper iron-bearing member, and (4) the upper black slate. These horizons indicate a continuous period of deposition, during which the conditions varied between those of chemical and probably also organic sedimentation, producing the iron-bearing formations, and those of mechanical sedimentation, with the production of the slates. It is believed that the general processes and agencies which produced the iron-bearing formations in this area are analogous to those which produced the iron-bearing members of the ranges on the south shore of lake Superior. These have been fully discussed in the monographs of the United States Geological Survey[3] on these districts, and are too well known to be here repeated. The change from chemical to mechanical sedimentation was not abrupt, as is shown by interstratification of and gradual transition between the two classes of deposits.

The two iron-bearing horizons are themselves quite different in character. The original rock of the upper horizon is a rather thin-bedded, cherty iron carbonate, similar to the cherty iron carbonates of the districts on the south shore of lake Superior. It varies in color from dark gray to very light colored, although the most characteristic phase of the unaltered carbonates is a dark and light banded rock, with the surface exposures usually showing brown limonitic weathering. In texture the formation varies from a dense homogenous rock, in which no definite mineral outlines can be distinguished, to one in which a carbonate cleavage is apparent, although in this latter case it is probable that the coarser carbonate crystals are secondary. A common phase of this horizon is a banded rock composed of alternating layers of iron

[3] Monographs of the U. S. Geol. Survey Nos. 19, 28, 36, 45 and 46.

oxide or partially altered carbonate and light or dark colored or red iron-stained chert. This phase is analogous to the banded ferruginous cherts and slates of the iron-bearing districts of the south shore. All stages of gradation can be observed from the original unaltered cherty carbonate rock through the ferruginous cherts and slates to iron ore.

The total thickness of this horizon is believed to be about 200 to 250 feet. The passage of the iron formation into the black slate above is not exposed in this area, but in the Mesabi district of Minnesota and elsewhere the change has been found to be that of gradual transition, and there is no reason to believe that it is otherwise here. At the base of the horizon however the gradation into the black slate is clearly shown, the iron formation becoming more thinly bedded, finely divided fragmental material appearing and becoming more abundant until typical black slate is reached.

The lower iron-bearing horizon can, except where extremely altered, be readily distinguished from the upper by the constant presence in it of small granules which are entirely absent from the upper horizon. Where the alteration of this rock to hematite has not gone far, it is very similar in appearance to the ferruginous cherts or "taconite" of the Mesabi range.[4] This is especially true where the granules are imbedded in a dense greenish or dark gray silicious matrix. Very frequently, however, in this area, the matrix surrounding the granules is largely carbonate material which varies from exceedingly fine to very coarse-grained. In this it differs from the ferruginous cherts of the Mesabi. Furthermore, although much of the carbonate material in this horizon appears clearly to be secondary, field observation would seem to indicate that part of it is original. The carbonate is not pure iron carbonate, but calcium-magnesium-iron carbonate.

In the Mesabi series the ferruginous cherts are themselves secondary products resulting from the alteration of the greenalite granules of an original "greenalite" rock. Chemically these granules are essentially hydrous ferrous silicate. In the Loon lake area, however, no unaltered greenalite granules were found, but what appear to be to be their alteration products (the granule-bearing rocks above mentioned) occur. Therefore it would appear that in this lower horizon there is represented a considerable period during which there was simultaneously deposited the two compounds of iron—iron carbonate and iron silicate—from which in the ranges of the lake Superior region as a whole the iron ores have resulted. But on the south shore these compounds have not been found occurring together in important amounts. As shown by Leith, in the Upper Huronian iron-bearing series of the Mesabi district, where the source of the ores is ferrous silicate, iron carbonate locally occurs, and in the Penokee-Gogebic district in which a cherty iron carbonate formation, also of Upper Huronian age and at the same stratigraphic horizon, was the original rock, ferrous silicate granules are subordinately present.[5] Therefore it is not surprising that at certain localities, of which the Loon lake area is an example, the conditions should have been such that the two materials were formed at the same time and in approximately equal amounts.[6]

Associated with the granule-bearing rock of the lower horizon, and in part at least secondary to it, are phases which show varying degrees of alteration to or replacement by iron oxide. Of the rocks of the formation which contain a high enough percentage of iron to be classed as ore, two phases are characteristic. One is a fine-grained red or blue hematite of medium hardness. The other is one whose texture is that of a medium to coarse-grained carbonate rock, but with the red color of hematite. That in this latter variety iron carbonate and iron oxide are both present is shown by chemical analyses of certain samples which give higher percentages of iron than is contained in iron carbonate.

[4] The Mesabi Iron-bearing district of Minnesota, by C. K. Leith. Mon. U. S. Geol. Survey No. 43, 1903, pp. 116-143.

[5] Mon. No. 43, cit., pp. 101, 118.

[6] The Iron Ore Deposits of the Lake Superior Region, by C. R. Van Hise. Twenty-first Ann. Rept. U. S. Geol. Survey, Vol. 3, 1901, pp. 319-320.

Conforming to the belief that this lower horizon was deposited close to the Animikie shore line is its comparatively small thickness, between 50 and 60 feet. It is, of course, probable that the thickness increases to the south.

THE CONCENTRATION OF THE ORE

The localities in which the greatest concentration of iron has as yet been proven are included in the area extending four miles west, two miles south and one mile east of Loon lake station. The greater portion of this area does not show outcrops of the Animikie strata, but it is known that the series is present under the overlying sandstone and diabase.

The concentration appears to have been determined by two main types of structural conditions:

(1) In the one case, the lower iron-bearing horizon is found lying on the south slopes of the graywacké-granite hills, with a comparatively uniform flat dip to the south. During the deformation which the series has undergone, sufficient movement occurred, both across and along the beds, to fracture and open them up, and thus produce conditions favorable for groundwater circulation.

The areas illustrating this type of structure include that portion of the Animikie area lying north and south of the Canadian Pacific railway, and west from Bittern lake about two miles, and the area south of Loon lake and west of Deception lake. In the latter area the iron formation is exposed practically at the surface, there being but from one to ten feet of overlying drift. In the former the lower horizon is generally capped by 10 to 35 feet of diabase. As the thickness of the lower horizon in this district is not great (50 to 60 feet), the question of commercial bodies of ore depends largely on the horizontal element. In both areas exploratory work has been done by test-pitting and diamond drilling. The result of the work thus far done shows that over the greater part of these areas the lower iron horizon has been extensively altered to iron oxide, but that associated with the layers showing the greatest concentration a considerable amount of lean silicious material is present, either as lenses in the hematite or as layers interbedded with it. Thus the average sample of any considerable vertical section is low grade. If it be found practicable to separate the lean material from the good ore, it should be possible to mine a large tonnage from these properties. However, until experiments on such separation have been made on a commercial scale, or until exploratory work has shown a large body of hematite free from lean material, no estimate of tonnage is possible.

Analyses of samples taken every three inches from four exposures representing vertical distances of six to eight feet each are given below. These are from the natural exposures which showed the greatest observed concentration, and include both the hematite and associated silicious material.

Fe.	P.	S.	SiO_2.
45.81	0.020	0.024	31.91
45.22	0.017	0.028	33.13
30.76	0.160	0.058	35.06
30.21	0.256	0.036	37.11

(2) The second structural condition which determined concentration is that of severe local deformation. This is mainly shown at or near the fault planes, where the movements have produced closely folded and brecciated rock masses. Here the conditions were again favorable for the circulation and work of ground water.

This phase of deformation is best illustrated in the Animikie area lying along the fault plane north of Deception lake and extending eastward to Silver lake, the area east of Deception lake, and that portion of the Animikie area located south and

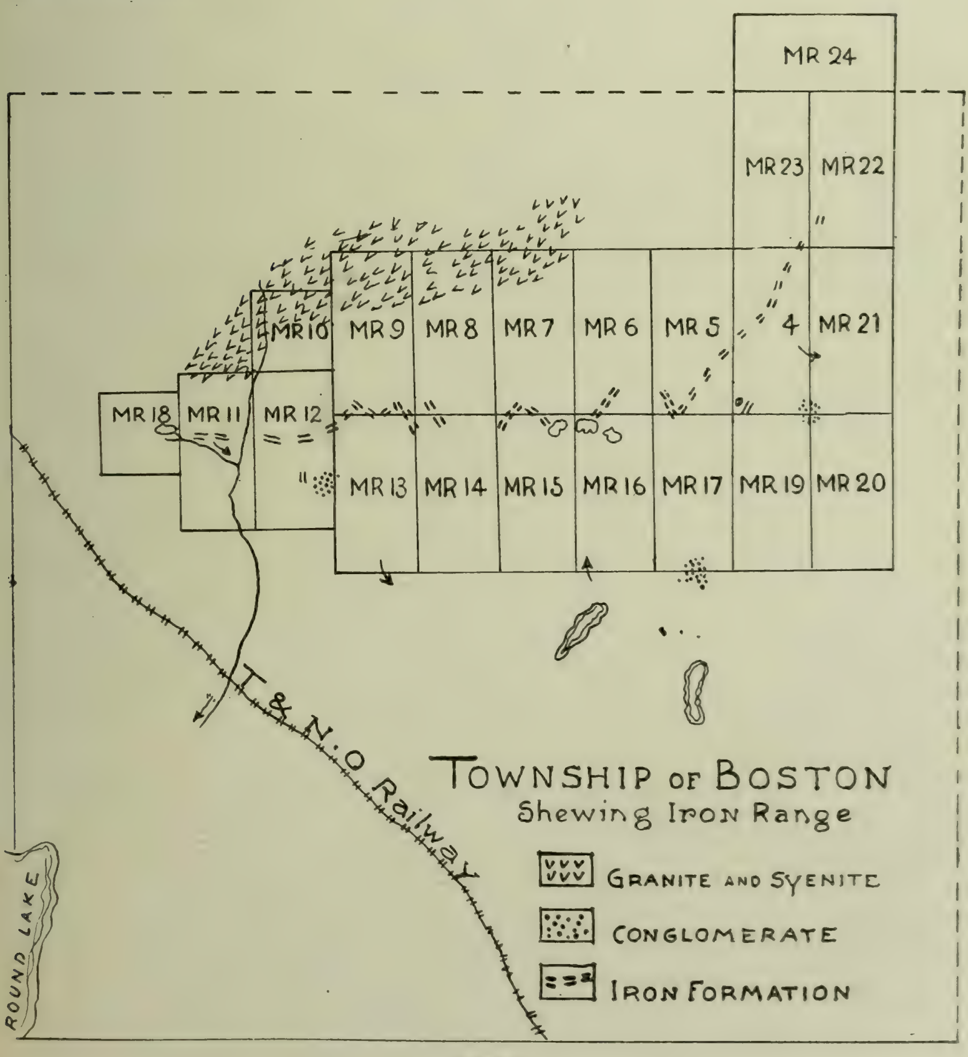
east of Bittern lake. On the above properties at various places both the upper and lower horizons of the iron formation are exposed. In these areas diamond drill holes have been put down, but the main work has been by test-pitting and driving short drifts into the iron formation on the hill sides. As in the previous case, the iron formation is found to be largely altered to iron oxide, but here also the layers showing the maximum concentration are frequently interbanded with lean material, or in the more brecciated phases contain masses of chert irregularly through the ore. The important question is again that of the economic separation of the lean from the commercial grade material.

The alteration of the iron formation has occurred both before and since Keweenawan time. The evidence of the pre-Keweenawan alteration lies in the abundant fragments of ferruginous chert and iron ore which occur in the Keweenawan conglomerates; that of the later alteration in the fact that the deformation which produced fracturing and brecciation of the iron formation, and which in part determined the concentration, was later than the Keweenawan time, as is shown by the similar phenomena of deformation in that formation.

BOSTON TOWNSHIP IRON RANGE

BY WILLET G MILLER

Two or three years ago an iron range was discovered in the township of Boston, which lies about fifty miles a little west of north of the town of New Liskeard, district of Nipissing. As the Bureau had no information concerning this range, it was decided to make an examination of it in the month of October last. We accordingly left Haileybury by steamer for Tomstown, and thence canoed up the main branch of the Blanche river to Round lake. From the northeast corner of this lake we portaged into the locations which had been surveyed. These locations are numbered M R 4 to M R 24 inclusive.



There being no trail from Round lake to the locations, it was necessary for us to find a route of our own. This we succeeded in doing without very much trouble.

It was found that the iron range has a crescent shaped form, curving from the northeast locations gradually south and west through the central locations; then turning northwestward it approaches the northeast corner of the township of Otto. Our work showed that the iron-bearing formation could have been covered by surveying out a much smaller area than has been applied for in Boston. The strike of the iron formation in the outcrops along the central east and west line of the locations is variable.

The township of Boston has been so thoroughly burned over that one has difficulty in getting firewood in places, especially in the autumn, sufficient to last for two or three days when camping in one spot. The central part of the township is high and rocky. From the central east and west line of the locations one can see mount Chanmanis and other hills which lie at a distance of twenty-five miles or more to the northeast.

There are a number of small lakes and streams on the locations which have been surveyed, and we were struck by the great number of beaver dams, still in use, which are to be found at the outlets of the lakes and along the courses of the streams.

GEOLOGY OF BOSTON

The rocks in this township belong to the pre-Cambrian, and consist of more or less altered and disturbed greenstones, quartz porphyry and related types. These cover practically all the southern two-thirds of the township. Part of the northern and northwestern portion of the township is occupied by granite and syenite, which cut the complex of igneous rocks just mentioned. There are some small exposures, or what may be called remnants, of a fragmental series. According to the nomenclature now proposed by the Geological Surveys of the United States and Canada, the series in this township would be represented in tabular form as follows:

Pre-Cambrian:

Trap dikes: Age uncertain.

Lower Huronian: Represented by small outcrops of conglomerate.

(Great unconformity).

Keewatin: Greenstones, quartz porphyry, etc. The iron formation is associated with the greenstones.

(Igneous contact).

Laurentian: Granite and syenite.

As the writer has not made a laboratory study of samples of all these rocks, the above brief description may not be strictly correct from the scientific point of view, but it will serve for economic purposes.

THE IRON FORMATION

The iron formation or jaspilyte in Boston is similar in character to that of Temagami and to those of other parts of Ontario, such as the Hutton township range, north of Sudbury, the Mattawin range west of Port Arthur, and the Vermilion range of the state of Minnesota.

The formation consists of iron ore, which in Boston is magnetite, interbanded with jasper and other closely related silicious material. Such an interbanded formation is known as jaspilyte. This formation has a length in Boston of approximately seven or eight miles. Another point in its favor, in addition to its length, is that it has been subjected to considerable disturbance by intrusions of igneous rocks. It has been much more disturbed than has the Temagami range or almost any of the other ranges which the writer has examined in Ontario or in the Lake Superior

region of the United States. To counterbalance these points in its favor, that is its length and its disturbed condition, we have to consider that its breadth is much less than that of the Temagami range or that of many other Ontario ranges. Some of these ranges have widths of 1,000 or 1,500 feet. Frequently their width is 500 or 600 feet. The width of the Boston iron formation is usually not more than 90 or 100 feet. The greatest width we saw in the township was about 300 feet. It would appear that the Boston range had originally a much greater width, but that it has been split up and separated by intrusions, and on this account presents comparatively narrow exposures.

LOCATION OF THE RANGE

Heretofore the township of Boston has been somewhat inaccessible, necessitating a canoe trip of about two days' duration from the steamboat landing at Tomstown on the Blanche river. The line of the Temiskaming and Northern Ontario railway has, however, been located across the western side of the township, and the road is now under construction almost to its southern boundary. The road runs very close to the western edge of the iron range.

OUTLINE DESCRIPTION OF THE LOCATIONS

The following description is copied from notes taken, from day to day, while in the field. Since some of the locations, numbered M R 4 to M R 24 inclusive, were visited on two or more occasions the references to them have been repeated.

The first point at which we encountered the survey lines of the locations when portaging into the range was on the southern boundary of M R 13, 300 yards east of the southwest corner post. From Round lake to this point the rock is the old greenstone of rather dark color, and more or less schistose structure. Near the location the color of the rock changes somewhat, becoming lighter, and having the appearance of an altered variety of a more acid type; it may, however, be a metamorphosed fragmental variety. At the point on the line referred to, the old light colored rock is cut by numerous small dikes of trap and also by granite like that which outcrops at Round lake.

Northern Boundary of Locations

Two hundred yards east of the northwest corner of 11 granite outcrops on the line and extends to the creek at the corner post, which is the northwest corner of 12. Going up the west boundary of 10, granite dies out in 100 yards, and the old dark rock, rusty in appearance, comes in about 200 yards up the line. The creek here runs north about parallel with the line and a little to the east. There is not more than about 100 yards of the old dark rock outcropping on this line. Most of the surface is occupied by a hornblende syenite which gradually becomes coarser in grain as we go north, resembling a boulder seen to the southward. The feldspar tends to take on a porphyritic structure. On the south edge there are occasional inclusions of a dark rock in the syenite. Two hundred yards east of the northwest corner of 10 the creek crosses the line. The syenite continues on the line eastward across the creek to the northeast corner of 10. From this point syenite outcrops to the northwest corner of lot 9. Thence it continues to the northeast corner of 9 and on to the northeast corner of 8. Across the northern boundary of 7 the syenite outcrops to within about 275 yards of the northeast corner post of this location, when some of the hornblende rock comes in and is seen to be cut by syenite. The corner post here is in a swamp. About 150 yards east of the post along the line, a bluff of the altered dark rock rises from the swamp. One hundred and twenty-five yards west of the northeast corner post of 6 there is a hill of rusty rock with much pyrite in places. The rock is quartzite-like, resembling some of that with which pyrite is associated near Net lake, Temagami. From the outcrop of the rusty rock the line runs east across a swamp which has a small stream in the middle of it. From here to the northeast

corner of 5 the line rises gradually up a hill, the surface of which is drift covered. Going up the west boundary of 23, the surface is mostly low and covered. Four hundred and fifty yards south of the northwest corner post of 23 there is an outcrop of rusty rock. Midway on this line a creek is crossed which flows eastward. The west side of 24 is nearly all swampy and covered. A third of the way up from the southwest corner post is an outcrop of the old dark rock, being the only outcrop seen here. On the west one-half of 23 there is only one outcrop also. The outcrop on 24 is just south of a little stream. Three hundred yards farther north is another little stream crossing the line. Along the north boundary of 24 the country is low and swampy. There is a creek crossing the line about 700 yards west of the northeast corner of the lot. A tie-line seems to form a continuation eastward of the north boundary. A trail runs from the creek mentioned southwestward.

East Boundaries of 24, 22, 21

No rock was seen on the north boundary, and there are no rock exposures on the east boundary of 24, the surface being low and more or less swampy. There is a creek within 25 or 30 yards north of the southeast corner of the location. A line runs eastward from this corner post. It is probably a tie-line. The east boundary of 22 from the northeast corner of this lot to within 400 yards of the southeast corner post is rather low and covered. Four hundred yards north of the southeast corner post the Keewatin rocks appear. A little over 100 yards north of the southeast corner post a brecciated-looking rock with matrix of crystalline limestone is exposed for about 50 feet along the line. The east side of 21 is covered for the most part, but there are a few exposures of the Keewatin, chiefly the lighter-colored varieties. The line runs on east from the southeast corner of 21.

South Boundary of 21, 4

Two hundred yards east of the southeast corner of location 4 conglomerate appears and outcrops at intervals to the post. Fifteen feet southeast of the post there is a bed of rock, which weathers like impure crystalline limestone, in the conglomerate. It has a width of about 6 feet and strikes northeast. There are also narrower bands of the same rock in the conglomerate. This limestone-like variety resembles rock seen in other parts of Boston, the character of which was not definitely determined. A road or trail crosses the line about 125 yards west of this post, and runs in a direction northwest and southeast. This is apparently the trail which joins the Blanche river to the southeast.

Northern Boundary of 18

Across the north boundary of this location the rock, which shows a more or less banded structure, belongs to the Keewatin series. The strike is apparently northwest, and the dip appears to be southwest at an angle of 60°. On the extension of this line westward in the unsurveyed territory the iron formation is seen a little to the south, a short distance west of the post. It is also seen on the east boundary of the township of Otto. These outcrops are small, only 10 or 15 feet in width. Following up the west boundary of the township, a creek was crossed, which is shown on the map on the west line of lot 1, concession 5, of Otto. A little specular hematite was seen just south of a hill. The boundary line is difficult to follow here. Turning west in Otto, the Keewatin series was exposed in numerous bare hills. A few hundred yards west of the line the greenstone schist contains calcite in cracks like those seen in the greenstone near the shore of lake Temiskaming. These cracks appear to have been produced by torsion.

North Boundaries of 11, 12, 13, 14, 15, 16, 17

Going south on the west boundary of 11 the rock appears to be the dark variety of the Keewatin. The surface is pretty well covered. Along the south boundary of this lot much of the surface is also covered. Going eastward from the southwest corner post, a creek is crossed about two-thirds of the way down the lot. Diabase outcrops on the line near the southeast corner post. The other rocks seen were the dark-colored greenstone of the Keewatin. There is a little rust in the rock near the southwest corner post.

Along the south boundary of 12 the rocks are well exposed. They consist chiefly of the dark varieties of the Keewatin, together with what appear to be altered felsite, quartz porphyry and a little newer diabase.

There is a considerable development of the very light-colored or white rock of the Keewatin along the south boundary of 13. This rock is similar in character to some of the pebbles which were found in the conglomerate mentioned a few paragraphs above. It is cut by syenite similar to that in the northwestern part of the township. Both the syenite and light-colored Keewatin are cut by trap dikes. There is a considerable development of trap or diabase a short distance up the west boundary of 13 from its southwest corner. A creek crosses the line about the middle of the southern boundary of 13. The dikes just referred to are immediately to the west of the creek. The old white rock continues to the southeast corner of the lot and beyond.

Across the south boundary of 15 the light-colored Keewatin, with an occasional dike of trap, is exposed. There is a lake about half a mile long, whose greatest diameter lies in a southwest direction 300 yards or so southeast of the southeast corner of 15.

Across the south end of 16 Keewatin rocks are exposed. They appear to be chiefly old traps with occasional dikes of later diabase. There is considerable swamp along the line. A creek flows north across the line 200 yards or so east of the southwest corner of the lot. Two hundred yards east of the southwest corner of 17, blocks of conglomerate with well-rounded pebbles a couple of inches or more in diameter were seen. This rock was not found in place here, but it appears not to have been transported far. Two hundred yards farther east an exposure of conglomerate-like rock with rather angular fragments appears. About half a mile south of this is a long narrow lake which strikes southward. The survey lines continue south from both the southwest and the southeast corners of 17.

The east boundary of 17, with the exception of the extreme north and south parts, is low and covered.

West Boundary of 13

On the west side of 13, along the survey line, from the southwest corner for a distance of 640 yards there is an alteration of the old, lighter-colored Keewatin rocks, trap and some felsite. At the 640 yards point there is a knoll of trap with a ravine just to the north.

At 750 yards north the rusty rock, containing considerable iron pyrites in places, comes in, the line running along the east edge of the rusty hill. The pyrites is in the light-colored variety of the Keewatin. At 1,300 yards up the line a little of the rock containing iron pyrites has been broken out just west of the line. The association of rock and mineral along this line is similar to that at some of the Temagami pyrite outcrops.

At about 1,500 yards up the line greenstone or trap comes in. The change, from the white rock of the south to the dark rock farther north, can be seen for some distance from the south. Then trap is passed over till we come to a band of the iron formation which crosses the line 75 yards south of the northwest corner post of 13. There is greenstone on the north edge of this outcrop, which is 35 feet in width and

consists of interbanded magnetite and light-colored silica. The greenstone is cut by a mica-bearing dike.

Near the northwest corner of 13 the more massive greenstone passes into a more disturbed variety, and 600 yards north of the southeast corner of 10 syenite begins to appear. Numerous dikes of this rock are seen along the line about 200 yards to the northward.

Locations 4, 23, 22

Going east along the north boundary of 4 a swamp is crossed. Two hundred yards east of the edge of this large swamp the iron formation begins. This is 300 yards west of the northeast corner of 4. The iron formation is probably 300 feet wide. It is leaner on the west and east sides, and so attracts the needle but little at these points. The strike is about northeast, where it crosses the line between 4 and 23, and the dip almost vertical, approaching the northwest.

Two hundred and sixty-five yards up the east boundary of 23 the iron formation crosses the line into 22. It appears to strike more north than northeast here and probably has a similar strike at the outcrop last mentioned.

Down the east boundary of 4 much of the surface is drift covered. A small stream is crossed about two-thirds of the way down the line. There are exposures of the older series and of the newer greenstones. Twenty yards north of the southeast corner post of 4 conglomerate, already referred to, outcrops and continues south to the post. It strikes northeast. Pebbles are abundant and vary in size up to about 3 inches.

West along the south boundary of location 4 the first 150 yards is probably conglomerate, being more or less covered, and then Keewatin greenstone rises into a hill. A little rust is seen in the rocks just east of the post. Going west along the line there is considerable rusty rock on the east half of the half mile with boulders of jaspilyte. Westward, 150 yards east of the southwest corner of 5, the jaspilyte comes in in outcrops of considerable width.

Mr. McCamus traced the iron formation southwest from the northeast corner of 4. It appears to cross the boundary of 5 and to be split up, an outcrop occurring near the camp in 4. Here, in the southwest corner of 4 about 25 yards southeast of a shanty, the jaspilyte is cut by two dikes. The band of iron formation here is about 200 feet wide. A mica trap dike runs northwest approximately and averages 6 to 10 feet in width. At its southeast end it cuts a felsite dike, which also cuts the iron formation and runs southwest approximately. The width of the latter dike is about 6 feet. The trap dike holds inclusions of granite, as does the smaller dike near by. A little creek cuts across the iron formation to the east, and the country is covered along the course of the iron formation to the eastward. To the north are large outcrops of rusty-weathering rock.

South Boundaries of 5, 6, 7, 8, 9

Following the southern boundary of 6 and 7 a trail is seen running along the north of the line to avoid a hill and a small lake. On the east end of the southern boundary of 6 is a high hill from which the country can be seen for miles around. Mount Chanmanis, which lies a short distance east of the inter-provincial boundary line near the forty-second mile post from lake Temiskaming, looms up with its characteristic haystack form.

Three of the outcrops of jaspilyte in location 6 along its southern boundary strike north and northeast. Outcrops are seen in 7 and one in 8, 100 yards east of the post. The strike was northwest and the dip, which was almost vertical, was to the east. The outcrop is about 25 feet in length. Near the southeast corner post of 9 there is a small outcrop of the iron formation, 5 or 6 feet wide. Its strike is northwest. On the same location, 200 yards west of the post, is an outcrop about 30 feet in length. The

strike is northwest. Fifty yards farther west is an outcrop which has a strike northwest and a width of about 30 feet. There appears to be one band which has been broken up by greenstone. In the swamp a short distance west is a mass of iron formation 10 or 12 feet in diameter, which might not be in place. Along the line for 100 yards or so east of the southwest corner of 9 the jaspilyte shows in outcrops a few feet in width and is much disturbed.

There is a swamp on the west half of 8. No outcrop was seen or determined by the dip needle 200 yards south of the east and west line or to the northward between lots 7 and 8.

Going north on the line between 7 and 8 the syenite is met with a quarter of a mile south of the north boundary. A rusty band lies to the south. The syenite rises into a hill along the north boundary.

Locations 11, 12, 18

Going west on the line between 10 and 12 a few feet of banded iron ore is seen 150 yards west of the corner post. At 264 yards a band has a width of 3 or 4 feet, and the strike is parallel with the survey line for a few yards. There is a creek at the northwest corner of 12. The post is situated on the west edge of the creek.

Four hundred and forty yards north of the southeast corner of 18 there are a few feet of banded ore which shows at the outlet of a creek which comes from a lake in 18. This lake lies immediately west of the line, and is not shown on the published map of the township. The gorge of the creek lies in the iron formation. There is an interesting little beaver dam across the creek at this point. Just southwest of this dam the banded rock is much wider than at the dam itself.

Jaspilyte outcrops across 11 and 12, between the east boundary of 18 and the west of 13. On 11 on the east face of the hill near the centre of the lot facing the creek bottom there is an exposure of jaspilyte with a total thickness of about 90 feet, interbanded with which are three layers of rock each about 4 feet wide. On lot 12 on the face of the hill, facing west into the creek bottom, is about the same width of jaspilyte. The iron formation seems to split up here, one part running east to the 35 feet band on the west boundary of 13, and the other north to the south boundary of 10.

The iron formation runs south in 12, and outcrops 300 yards west of the 600 yard point north of the southwest corner of 13. It occurs on both sides of the north and south line between 11 and 12 in this part of the field.

The distribution of the outcrops of the iron formation in 12 illustrates the disturbance to which it has been subjected in Boston. Three have been referred to in the location; one crossing the line between 12 and 13, near the northwest corner of the latter; another on the line between 10 and 12, about 200 yards from the northeast corner of 12; while a third outcrop is that referred to above. It lies 300 yards west of a point on the west boundary of 13, the point being 600 yards north of the southwest corner post of this location.

Conglomerate appears 300 yards west of the 600 yard point north from the south end of the west boundary of 13.

CONGLOMERATE

The conglomerate outliers which were met with, as shown by the above description of the locations, are three in number, if we except one which has a matrix of crystalline limestone. These are (1) at the southeast corner of 4, (2) on the southern boundary of 17, (3) on the south half of 12.

This conglomerate probably was at one time a widespread formation here but has been removed by erosive agencies. It is probably of the same age as that in which the cobalt-silver veins occur near lake Temiskaming. The township of Boston lies at a greater elevation than the outcrops near Temiskaming. Hence its surface has been subjected to more severe erosion.

ROCKS NEAR ROUND LAKE

Some of the rocks in the vicinity of Round lake and in the township of Otto are described in a report made by Mr. L. L. Bolton to the Bureau of Mines, and published in the 12th Annual Volume.

The present writer did not spend much time around the lake but made the following notes:

The rock near the south end of the east boundary of Otto is syenite with dark inclusions which are more or less rounded. These dark patches no doubt represent fragments of the Keewatin which have been enclosed and partly absorbed by the intrusive granite magma. Going around the eastern edge of Round lake similar outcrops are seen. Continuing the canoe route down the river, the rock seen on the shores is chiefly granite, with dark inclusions, to the point where the north branch joins the Round lake branch of the Blanche.

PRE-CAMBRIAN NOMENCLATURE[1]

[Introductory note by C. R. Van Hise]

The report below of the special committee on the nomenclature and correlation of the geological formations of the United States and Canada is the first joint report of the geologists of the two countries. Before the death of Dr. G. M. Dawson, formerly director of the Canadian Geological Survey, I had correspondence with him in reference to joint field-work in the lake Superior region. It was agreed between us that such field-work should be undertaken, but his untimely death occurred before anything was done.

After Dr. Dawson's death I continued correspondence upon the subject with Dr. Robert Bell, acting director of the Canadian Geological Survey. As a result of this correspondence, December 22, 1902, Dr. Bell wrote to Dr. C. D. Walcott, director of the United States Geological Survey, suggesting a conference in reference to the mutual interest of the two Surveys. This letter led to the appointment of a committee—consisting of C. W. Hayes and C. R. Van Hise, for the United States Geological Survey, and Robert Bell and Frank D. Adams, for the Canadian Geological Survey—to consider all questions as to the successions of formations, and as to nomenclature, which concerned the two Surveys.

This committee, with C. W. Hayes as chairman, met for the first time at Washington, January 2, 1903. At this meeting several special committees were appointed to consider different districts along the international boundary. For the lake Superior region the following committee was appointed; for the United States, C. R. Van Hise and C. K. Leith, of the United States Geological Survey, and A. C. Lane, state geologist of Michigan; and for Canada, Robert Bell and Frank D. Adams, of the Canadian Geological Survey, and W. G. Miller, provincial geologist of Ontario.

August 3, 1904, this special committee met in the Marquette district of Michigan, and during the six weeks following visited successively the Gogebic, Mesabi, Vermilion, Rainy lake, Lake of the Woods, Animikie, and original Huronian districts. After finishing the field-work, a report in preliminary form was drawn up.

In December, 1904, another meeting of the special committee was held at Philadelphia, further to consider the report, all members of the committee being present except C. R. Van Hise. At this meeting the report of the sub-committee was completed as given below.

REPORT OF THE COMMITTEE

Your special committee on the lake Superior region, during the months of August and September, 1904, visited various districts in the lake Superior country, their purpose being to ascertain, if possible, whether they could agree upon the succession and relations of the formations in the various districts, and could further agree upon a nomenclature appropriate to express the facts. The districts visited were the Marquette, the Penokee-Gogebic, the Mesabi, the Vermilion, the Rainy lake, the Lake of the Woods, the Thunder Bay, and the original Huronian to the north shore of Lake Huron. Aside from the regular members of the special committee, for parts of the trip other geologists were with the party. Dr. C. W. Hayes, geologist in charge of geology, United States Geological Survey, and a member of the general committee, was with the party for the Marquette, Penokee-Gogebic, Mesabi, Vermilion, and Rainy lake districts. Professor A. E. Seaman was with the party for

[1] Report of International Committee on Lake Superior Geology; from the *Journal of Geology*, February-March, 1905.

the Marquette, Penokee-Gogebic, Rainy lake, Lake of the Woods, and Thunder Bay districts. Mr. J. U. Sebenius was with the party for the Mesabi district, Mr. W. N. Merriam, for the Mesabi and Vermilion districts; Mr. W. N. Smith, for the Thunder Bay district; Mr. E. D. Ingall and Mr. T. D. Denis, for the Lake Huron district. The knowledge of these men was of great assistance to the committee.

In the following pages we shall give the successions and relations of formations which we believe to obtain for each of the districts visited, and give our opinion as to the major correlation of the rock series of the various districts, so far as this can be safely done, and the nomenclature which seems to best express the facts.

For each district, unless otherwise specified, the succession will be considered in descending order. In giving the successions for the various districts, we shall use, for convenience, the names suggested by geologists who have done the detailed work in the districts, without thereby expressing any opinion as to their appropriateness or their advisability.

In the Marquette district we found the upper series there exposed to be as follows: (1) Michigamme slate and schist, and (2) Ishpeming formation. Locally within the Michigamme slate, and apparently near its base, is an iron-bearing horizon. The Clarksburg volcanics, said to be a local phase of the Michigamme formation, were seen at Champion. The basal member of the Ishpeming formation is the Goodrich quartzite. This series, called the upper Marquette series by the United States Geological Survey, has at its base a pronounced unconformity, marked by extensive beds of conglomerate, having materials of diverse character. The dominant fragments of the conglomerate at the localities visited are from the Negaunee formation to be mentioned below. The next series is the Middle Marquette series, consisting of (1) the Negaunee formation, (2) the Siamo slate, and (3) the Ajibik quartzite. In the publications of the United States Geological Survey this series was not separated from the series next mentioned, but the work of Professor Seaman has shown that there is a pronounced unconformity, marked by strong basal conglomerates at the bottom of the Ajibik. Below this unconformity is the Lower Marquette series, consisting of (1) the Wewe slate, (2) the Kona dolomite, and (3) the Mesnard quartzite. At the places where we saw the succession there is a belt of slate between the Kona dolomite and the Mesnard quartzite of such thickness that it might possibly be mapped as a formation if the exposures were more numerous. The members of the United States Geological Survey think that this slate is probably general for the district, as it shows wherever the exposures are continuous from the dolomite to the quartzite. At the base of the Lower Marquette series is an unconformity, marked by conglomerates bearing fragments of all the kinds of rocks seen in the underlying series. Two classes of fragments are especially abundant. These are (1) tuff, greenstone schist, and many kinds of greenstones which belong to the so-called green-schist series of the district, and (2) various kinds of granite and gneissoid granite. Adjacent to the state road south of the city of Marquette the actual contact was seen between the two series, the basal conglomerate resting upon the green schist. The great variety of materials in this conglomerate and the well-rounded character of the fragments left no doubt in the minds of the members of the party that there is a great structural break at the base of the Lower Marquette series.

The lowest group of the Marquette district is a very complex one, which has been designated as the Basement Complex. It consists of two classes of material—the greenstone-schist series, and the granites and gneissoid granites. The greenstone schist series is especially well known through the description of the late George H. Williams, found in Bulletin 62 of the United States Geological Survey. This series is designated on the maps of the Marquette Monograph as the Kitchi and Mona schists. Instrusive in the green schist series are great masses of granite and gneissoid granite. No evidence was seen by the party that any of the granites intrude the sedimentary series above the green-schist series, although Seaman thinks in one

place a small mass of granite does intrude the Lower Marquette series. It is believed that the great masses of granite of the district antedate the three series here called Upper, Middle and Lower Marquette.

In the Penokee-Gogebic district the highest rocks seen are the Keweenawan traps and interbedded sandstones, the bedding of which dips at a high angle to the north. No actual contact between the Keweenawan and the next underlying series was seen, but north of Bessemer, below the Keweenawan, the next formation is the great Tyler slate formation of the Penokee series, while at Sunday lake the Keweenawan rests directly on the iron-bearing formation which is stratigraphically below the slate. This relation led the party to infer the existence of an important unconformity between the two. The Penokee-Gogebic, or iron-bearing series, consists of (1) the Tyler slate, (2) the Ironwood formation, and (3) the Palms slate This Palms slate was seen to rest directly upon granite south of the Newport and Palms mine. At the former locality there is no conglomerate at the base. At the latter locality there is a conglomerate at the base of the slate which, besides containing granite detritus, also contains many cherty fragments supposed to be derived from the next underlying sedimentary series.

East of the Presque Isle river the lower sedimentary succession of the Penokee-Gogebic district was visited, here consisting of (1) cherty limestone and (2) quartzite. The quartzite dips to the north at a moderate angle and rests upon green schist. The two formations were seen in direct contact for a hundred feet or more. The cleavage of the green schist abuts against the bedding of the quartzite at right angles. The quartzite near its base passes into a conglomerate, which, just above the contact becomes very coarse and contains very numerous well-rolled fragments of the immediately subjacent schist. The unconformity at the base of the quartzite could not be more pronounced.

The party nowhere saw the relations of the limestone-quartzite series just described and the Penokee-Gogebic series proper, but they have no reason to doubt the conclusion of the United States Geological Survey that the limestone-quartzite series is the inferior one.

The relations of the green schist, called Mareniscan by the United States geologists, and the granite, which together constitute the basement upon which the determined sedimentary series of the dictrict rest, were not studied by the party. The United States geologists hold that the relations are perfectly clear, and that the granitic rocks are intrusive in the green schist.

In the Mesabi district the succession of the Mesabi series is as follows: (1) Virginia slate, (2) the Biwabik iron formation, and (3) the Pokegama quartzite. This series dips at a gentle angle to the south. At the base of this series at Biwabik is a conglomerate which rests upon a series of slates and graywacké, the latter in nearly vertical attitude. The unconformity between the two is most pronounced. The slate and graywacké where crossed has a considerable breadth. It flanks a green-schist series. The slate and graywacké formation adjacent to the green-schist is conglomeratic. Many of the fragments of the conglomerate are from the underlying green schists. At the locality visited it could not be asserted that the break between the slate-graywacké formation and the green-schist series is great. although nothing was seen which is contrary to this view. The granite constituting the Mesabi range is reported by the United States geologists as intruding both the green-schist and the slate-graywacké series, but not the Mesabi series. At the east end of the district a newer granite is reported as intruding both the Mesabi and the Keweenawan series, and in the central portion of the district small areas of granite porphyry are reported as antedating the slate-graywacké series.

In the Vermilion district the Upper series, where seen, consists of (1) Knife slates and (2) Ogishke conglomerate. The Ogishke conglomerate contains very numerous fragments of all the underlying formations noted—porphyries, green schists, iron formation, granite—and we have no doubt that there is a great structural break

at the base of the Ogishke. The series below this unconformity, the Vermilion series, consists of (1) the Ely greenstone and (2) the Soudan formation. The Ely greenstone is the dominant formation. It is mainly composed of green schists and greenstones, many of which show the ellipsoidal structure described by Clements. The other important formation of the Vermilion series is the Soudan iron formation. The structural relations of the Ely greenstone and the Soudan formation are most intricate. No opinion here expressed as to their order. The Ely greenstone and the Soudan iron formation are cut by porphyries, and, according to the reports of the United States Geological Survey, are cut in a most complex way by the great northern granite, but the localities ilustrating this were not visited. It is worthy of mention that the United Sates geologists report granite as intruding the Knife slates and Ogishke conglomerates in the central parts of the district, especially in the vicinity of Snowbank lake, but this locality was not visited by the party.

In the Rainy lake district the party observed the relations of the several formations along one line of section at the east end of Shoal lake and at a number of other localities. The party is satisfied that along the line of section most closely studied the relations are clear and distinct. The Couchiching schists form the highest formation. These are a series of micaceous schists graduating downward into green hornblendic and chloritic schists, here mapped by Lawson as Keewatin, which pass into a conglomerate known as the Shoal lake conglomerate. This conglomerate lies upon an area of green schists and granites known as the Bad Vermilion granites. It holds numerous large well-rolled fragments of the underlying rocks, and forms the base of a sedimentary series. It is certain that in this line of section the Couchiching is stratigraphically higher than the chloritic schists and conglomerates mapped as Keewatin. On the south side of Rat Root bay there is also a great conglomerate belt, the dominant fragments of which consist of green schist and greenstone, but which also contain much granite. The party did not visit the main belts colored by Lawson as Keewatin on the Rainy lake map, constituting a large part of the northern and central parts of Rainy lake. These, however, had been visited by Van Hise in a previous year, and he regards these areas as largely similar to the green-schist areas intruded by granite at Bad Vermilion lake, where the schists and granites are the source of the pebbles and boulders of the conglomerate.

In the Lake of the Woods area one main section was made from Falcon island to Rat Portage, with various traverses to the east and west of the line of section. The section was not altogether continuous, but a number of representatives of each formation mapped by Lawson were visited. We found Lawson's descriptions to be substantially correct. We were unable to find any belts of undoubted sedimentary slate of considerable magnitude. At one or two localities, subordinate belts of slate which appeared to be ordinary sediment, and one belt of black slate which is certainly sediment, are found. In short, the materials which we could recognize as water-deposited sediments are small in volume. Many of the slaty phases of rocks seemed to be no more than the metamorphosed ellipsoidal greenstones and tuffs, but some of them may be altered felsite. However, we do not assert that larger areas may not be sedimentary in the sense of being deposited under water. Aside from the belts mapped as slate, there are great areas of what Lawson calls agglomerate. These belts, mapped as agglomerates, seem to us to be largely tuff deposits, but also include extensive areas of ellipsoidal greenstones. At a number of places, associated and interstratified with the slaty phases are narrow bands of ferruginous and siliceous dolomite. For the most part the bands are less than a foot in thickness, and no band was seen as wide as three feet, but the aggregate thickness of a number of bands at one locality would amount to several feet.

We could discover no structural breaks between the above formations of the Lake of the Woods. The various classes of materials—slates, agglomerate and ellipsoidal greenstones—all seem to belong together. In short, these rocks in the Lake of the Woods seem to us to constitute one series which is very largely igneous

or volcanic in origin, but does, as above mentioned, contain some sediments. This series in the Lake of the Woods area is the one for which the term "Keewatin" was first proposed for the greenstone series, Lawson giving as one reason for proposing this name the statement that there is no evidence that these rocks are equivalent with the rocks of Lake Huron described by Logan and Murray as Huronian.

The ellipsoidal greenstone-agglomerate-slate series is cut in a most intricate way by granite and granitoid gneiss, which constitute much of Falcon island at the southern part of the Lake of the Woods and a great area north of the Lake of the Woods. These relations between the granite and Keewatin were seen on the northwest part of Falcon island and on a small island adjacent. They were also seen north of Rat Portage. At the latter place the rocks adjacent to the granite are banded hornblende and micaceous schists, very similar to the banded rocks of Light House point, at Marquette. At Hebe falls the granite and Keewatin series are seen to be in actual contact, the Keewatin being apparently intruded by the granites, although the relations have often been interpreted as conformable gradations. Going north along the Winnipeg river, the relations between the two series become perfectly clear. Great blocks of the Keewatin are included in the granite, the masses varying from those of small size to others of enormous bulk. Also the two have intricate relations, which have perhaps been best described as *lit par lit* injection. In short, the relations are those so well described by Lawson for this area.

In the Thunder Bay district we visited especially the areas about Loon lake and Port Arthur. In the Loon lake area the succession is as follows: The top series is the Keweenawan, here consisting of sandstone above and conglomerate below, with interbedded basic igneous flows or sills. Below the Keweenawan is the Animikie. The contact between the Keweenawan and the Animikie was seen at two places. At one of these there is an appearance of conformity, but at the other the eroded edges of the Animikie iron-bearing formation are traversed by the Keweenawan beds. At one contact the base of the Keweenawan rests on the Animikie slate, interstratified with the iron formation, and at the other on one of the members of the iron-bearing formation. At both localities the conglomerate at the base of the Keweenawan bears detritus from the underlying series, including both the slate and the iron-bearing formations of the Animikie. The Animikie succession which we saw near Loon lake includes two phases of the iron-bearing formation with an interstratified belt of slate. The Animikie here has in general rather flat dips, although locally they become somewhat steeper.

Near Port Arthur the higher slate member of the Animikie was visited by a portion of the party, and on previous occasions had been visited by the other members. This is the formation which is agreed by all to rest upon the Animikie iron formation. It is notable as containing the intrusive sills called by Lawson the Logan sills.

At one place near Loon lake a test pit has been sunk to the bottom of the Animikie, and here at the base of the formation is a conglomerate bearing fragments of the next underlying series—a graywacké slate. This graywacké slate covers a large area, shows cleavage at a high angle, and is evidently an important formation in the district.

The party has no doubt that there is considerable unconformity between the Keweenawan and the Animikie, and a very important unconformity between the Animikie and the graywacké slates.

A portion of the party went north from Port Arthur to see the green-schist and granite series. This was found, but seen only in small volume at the particular area visited. At other times several members of the party have visited larger areas of this green-schist and granite complex north and northwest of Port Arthur in Gorham, Conmee, and other townships, and in the green schists they found an iron-bearing formation analogous in character to the Soudan formation of the Vermilion district. The granites are intrusive in the greenstones.

At no place were the relations between the graywacké slate series below the Animikie and the green-schist granite complex observed.

In the original Huronian area—i. e., the area described by Logan and Murray as extending from near Sault Ste. Marie along the north shore of Lake Huron to Thessalon and northward—we examined a number of crucial localities. At the first of these, about five miles from Sault Ste. Marie, near Root river, we studied the relations of the conglomerate, mapped as lower slate conglomerate by Logan, with the granite. The conglomerate is in a vertical position. We found the upper horizon of the conglomerate near the road to be of moderate coarseness, and to contain many fragments of green schist, greenstone and granite. The granite fragments increase in prominence and size toward the north, and at the north end of the exposure we have a great granite conglomerate. After an interval of a few paces we found to the north a red granite similar to many of the fragments of the conglomerate. The party has no doubt that the conglomerate rests unconformably upon the granite. This conglomerate, while mapped by Logan as lower slate conglomerate, appears to be above a limestone next to be mentioned, and has been connected by Van Hise and Leith with rocks like the red quartzite belonging above the limestone, and they believe it to be the upper slate conglomerate rather than the lower slate conglomerate, although the overlapping recent lake deposits prevent the connection by actual areal tracing. A short distance east of the point where the conglomerate is next to the granite and north of the great mass of the conglomerate is a belt of limestone which continues east for perhaps half a mile. North of this limestone is conglomerate, and still to the north, granite. This northern conglomerate is very similar to the conglomerate south of the limestone, and two interpretations are possible as to its position: it may be regarded as the lower slate conglomerate under the limestone or it may be regarded as an equivalent to the conglomerate south of the limestone, being repeated by an anticline or possibly a fault. The limestone has a steep dip to the north, and, accepting either alternative, it must be regarded as overturned.

We next visited the abandoned limestone quarry north of Garden river station. Here we found the conglomerate, marked by Logan as the upper slate conglomerate within a few paces of the limestone. This conglomerate is in all respects similar to the average of the conglomerates before mentioned, except that it contains very numerous limestone fragments. The party has no doubt that the limestone formation was laid down, and that a considerable erosion interval occurred before the deposition of the conglomerate upon the limestone. The slate-conglomerate belt north of the limestone was examined, and while it was not found in contact with the limestone, it was seen to increase in coarseness as the limestone is approached, and across the little ravine which separates the conglomerate from the limestone it was found to contain numerous limestone fragments. We therefore conclude that the rock on each side of the limestone is the upper slate conglomerate, the structure being anticlinal, possibly with faulting. This conclusion suggests that the same relation obtains at the Root river locality above described.

On the limestone point on the east side of Echo lake we found the following ascending succession, with monoclinal dip to the southeast: (1) white or gray quartzite, grading through graywacké into (2) a thin belt of conglomerate not exceeding twenty feet in thickness and containing numerous granite fragments. Above the conglomerate is (3) limestone in considerable thickness, and over this (4) the upper slate conglomerate. This last is a thick formation. The upper conglomerate is very coarse near the limestone, and becomes finer in passing away from the limestone along the lake shore. Like the conglomerate near Garden river, it bears very numerous limestone fragments, the evidence of which is beautifully seen at the lake shore, where the water has dissolved many of them completely and others in part. The ledge thus presents a deeply pitted surface, many of the pits being several inches in depth.

On the west side of Echo lake we ascended the prominent bluff next north of the west limestone point, and here found the formation nearly horizontal, but dipping slightly into the hill. The quartzite in this position composes the greater part of the bluff. A short distance from the top we found the quartzite grading upward into a graywacké-like rock, and this into a conglomerate which contains granite and green-schist fragments; indeed, it is typical slate conglomerate. This conglomerate is only a few feet in thickness, and above it appears a siliceous limestone, and above this, normal limestone like that of Garden river and the east side of Echo lake. The total thickness of the limestone here seen was probably not more than fifty feet, and of the conglomerate below, not more than thirty feet. The lower five hundred feet or more of the bluff is the white quartzite.

The other bluffs on the west side of the lake were not visited by the party, but Leith, Seaman, and Van Hise have examined each of these bluffs, and found the succession above given to obtain upon each prominent bluff, with the exception that on the next bluff to the north the limestone is wanting, so far as observed. The limestone is also in greater force on some of the other bluffs, but is always subordinate in thickness to the quartzite. It thus appears that the great formation on the west side of Echo lake is the quartzite; that the limestone above appears, not as a single belt, but as a number of synclinal patches often capping the hills; and that the conglomerate showing both north and south of the limestone is a very thin foundation between the quartzite and the limestone, and is, therefore, the lower slate conglomerate.

Our observations from Root river to Echo lake convince us that there is a considerable structural break in the Huronian. The upper series includes the following formations of Logan, viz.: white quartzite, chert, and limestone, yellow chert and limestone, white quartzite, red jasper conglomerate, red quartzite, and upper slate conglomerate. The lower series includes the lower limestone of Logan and the lower slate conglomerate, white quartzite, and gray quartzite. North of Thessalon the two series are represented by Logan and Murray as being separated by a fault. Here the distribution may be explained by the unconformity mentioned, but it is also entirely possible that the relations are due to faulting or to both unconformity and faulting.

Four miles east of Thessalon on several islands off the coast is a great conglomerate, mapped by Logan and Murray as a gray quartzite. This conglomerate was found to rest unconformably upon the granite, the actual contact being observed upon one island opposite the northwest quarter of section 12 of the township of Thessalon. The fragments in the conglomerate are well rounded and are largely granite, but there are numerous pebbles and boulders of greenstone and green schist. On several islands adjacent to the conglomerate the massive granite includes many fragments of greenstone and green schist, showing the granite to be intrusive into a greenstone formation. Thus in the complex against which the conglomerate rests we have a source both for the granite and greenstone pebbles and boulders. To the northwest the conglomerate grades up by the interstratification into a quartzite. About a quarter of a mile west of the conglomerate, near the north end of a point, the quartzite is found to become a fine conglomerate, and to rest against greenstone which is cut by a large granite dike. The greenstone shows ellipsoidal parting. The granite dike strikes toward the conglomerate and the quartzite, but it dies out into a depression showing no rock, which continues to the quartzite some fifty or sixty feet distant. The quartzite and conglomerate strike directly across this depression, showing continuous exposures, and are not cut by granite. The relations here are believed by certain members of the party to show clearly that the quartzite and conglomerate rest unconformably upon the greenstone, but other members felt that this conclusion is not certain. The conglomerate and gray quartzite are cut by greenstone dikes. Similar rocks also cut the Thessalon series referred to below.

The rocks called green chloritic schist by Logan (3c) will here be called the Thessalon series. This series consists of ellipsoidal greenstones, amygdaloids, agglomerates, and massive greenstones. No undoubted sediments were observed in the series. The relations of the Thessalon series to the granite were observed southeast of Little Rapids, and it was found that the granite cuts the greenstone series in an intricate fashion. The belt of gray quartzite, mapped as extending inland for a number of miles between the Thessalon series and the granite, was found to be absent at this locality. Two or three miles east of Thessalon, felsite and granite in considerable masses were found to intrude the Thessalon series. At one place several felsite or granite dikes were observed to cut both the agglomerates and ellipsoidal greenstones. From the relations observed, the party had no doubt that the conglomerate islands east of Thessalon belong unconformably upon the granite, and they think it probable (Van Hise would say highly probable) that the quartzite and conglomerate rest unconformably upon the Thessalon series, mapped as green chloritic slate by Logan and Murray. It is regarded as probable that the white quartzite below the lower slate conglomerate northwest of the Thessalon series which is adjacent, and is shown by its dip to rest upon the Thessalon series, is separated from that series by an unconformity, but no direct evidence of such relation was observed.

The Thessalon series should be excluded from the Huronian if, as believed, the unconformity just mentioned exists. If this series be excluded, the Huronian of Lake Huron consists of two series, an Upper Huronian and a Lower Huronian. The Upper Huronian extends from the top of the series, as given by Logan and Murray, downward to and including the upper slate conglomerate; and the Lower Huronian extends from the main limestone formation to the gray quartzite, including its basal conglomerates. In the area mapped by Logan on the north shore of lake Huron the Laurentian consists of granite and gneissoid granite, with subordinate inclusions of greenstone.

We do not feel that our examination of the Lake Superior region was sufficiently detailed to warrant an attempt at correlation of the individual formations of the various districts. There are, however, certain general points which seem to be reasonably clear, and about which there is no difference of opinion between us. These are as follows:

There is an important structural break at the base of the Keweenawan. The term "Keweenawan" should include substantially all of the areas which have been thus mapped, or mapped as Nipigon, by the Canadian and United States Surveys, and the State Surveys of Michigan, Minnesota and Wisconsin.

Below the Keweenawan is the Huronian system, which in our opinion should include the following series; In the Marquette district, the Huronian should include the Upper and Lower Marquette series, as defined in the monographs of the United States Geological Survey, or the Upper, Middle, and Lower Marquette series, as given in the previous paragraphs. In the Penokee-Gogebic district, the Huronian should include the series which have been called the Penokee-Gogebic series proper, and the limestone and quartzite which have local development, and which we visited east of the Presque Isle river. In the Mesabi district, the Huronian should include the Mesabi series proper, and the slate-graywacké-conglomerate series, unconformably below the Mesabi series. In the Vermilion district, the Huronian should include the Knife slates and the Ogishke conglomerates. In the Rainy lake district, the Huronian should include that part of the Couchiching of the south part of Rainy lake which is limited below by basal conglomerate as shown at Shoal lake. In the Thunder Bay district, the Huronian should include the Animikie and the graywacké series in the Loon lake area. In the original Huronian area, the Huronian should include the area mapped by Logan and Murray as Huronian, except that the Thessalon greenstones should probably be excluded.

Unconformably below the Huronian is the Keewatin. The Keewatin includes the rocks so defined for the Lake of the Woods area and their equivalents. We

believe the Kitchi and Mona schists of the Marquette district (Marcniscan) of the Penokee-Gogebic district, the greenstone series of the Mesabi district, the Ely greenstones and Soudan formation of the Vermilion district, the part of the area mapped as Keewatin by Lawson in the Rainy lake district not belongong structurally with the Couchiching, and probably the Thessalon grenstone series on the north shore of Lake Huron, to be equivalent to the Keewatin of the Lake of the Woods, and, so far as this is true, they should be called Keewatin.

For the granites and gneissoid granites which antedate, or protrude through, the Keewatin, and which are pre-Huronian, the term "Laurentian" is adopted. In certain cases this term may also be employed, preferably with an explanatory phrase, for associated granites of large extent which cut the Huronian, or whose relations to the Huronian cannot be determined.

The following succession and nomenclature are recognized and adopted:

CAMBRIAN—Upper sandstones, etc., of lake Superior.

Unconformity

PRE-CAMBRIAN

Keweenawan (Nipigon)[1]

Unconformity

Huronian
- Upper (Animikie)
- *Unconformity*
- Middle
- *Unconformity*
- Lower

Unconformity

Keewatin

Eruptive contact

Laurentian

Alphabetically signed by the committee as follows:

FRANK D. ADAMS,
ROBERT BELL,
A. C. LANE,
C. K. LEITH,
W. G. MILLER,
CHARLES R. VAN HISE,
Special Committee for the Lake Superior Region.

[1]Dr. Lane dissents as to the position of the Keweenawan as follows:
"The use of pre-Cambrian above does not imply unanimity in the committee with regard to the pre-Cambrian correlation of the Keweenawan—a topic the committee as such did not investigate."

IRON RANGES OF MICHIPICOTEN WEST

BY J M BELL

The Michipicoten Huronian Area

Since the first discovery of iron ores in the Lake Superior region, it has been a matter of very general observation that these ores occur within the limits of belts of rocks of certain definite characteristics. These belts of iron-bearing rocks are generally known as ranges. The word "range" does not imply a mountain chain or ridge; but is used in a loose sense, merely to indicate that the iron-bearing rocks trend in a general linear direction, and that the area occupied by them at the surface is much greater in longitudinal section than in cross-section. Often, however, the iron-bearing rocks occupy a prominent position in the landscape in which they occur, and are relatively mountainous as compared with the rocks of generally faint relief with which they are associated. Hence, in a way, even in the correct sense the word "range" is not inappropriate.

On the United States side of Lake Superior there are several prominent belts of iron-bearing rocks. Important among them are the Marquette Range, the Menominee Range, the Penokee-Gogebic Range, the Mesabi Range and finally the Vermilion Range. On all of these iron ranges monographs have been written which have been of great value to the miners and prospectors of the country. Each range has produced, and is still, annually, producing immense quantities of iron ore.

On the Canadian side of Lake Superior we, also, have belts of iron-bearing rocks, though these have as yet not proved so important as on the other side of the line. Among these ranges may be mentioned the Mattawin, the Atikokan, the Animikie, the Nipigon, the Michipicoten, the Batchawana, the Hutton and the Temagami. Though these various ranges have been examined in a more or less cursory manner, very little systematic work has up to the present been undertaken. Only one of these ranges, the Michipicoten, is at present an iron producer, but there is apparently no reason why with further exploration several or all of them may not be found to contain ore-bodies of value.

It was with the especial object of making a careful examination of the Michipicoten iron range that the writer was instructed by the Director of the Bureau of Mines to make a geological survey of the Michipicoten Huronian area. The area lies on the north shore of Lake Superior, encircling Michipicoten bay, and is for the most part included within the boundaries of the Michipicoten Mining Division set apart by the Ontario Government in 1897, but some of the Huronian rocks lie beyond the limits of the division. The Huronian rocks have a surface area of some 1,700 square miles, and are contained between N. lat. 47° 30' and N. lat 48° 30', and longitude 84° west and longitude 86° west. The area may be divided into four divisions. The south section includes all Huronian rocks from the point some four or five miles north of Point Gargantua, where they first appear on the Lake Superior shore, to the Michipicoten river, and as far east as the mouth of its tributary, the Sequamka. All bands of iron-bearing rock within this stretch make up the south Michipicoten Iron Range. The east section of the Huronian area extends eastward from the Magpie river to the Michipicoten and Sequamka, and contains the east Michipicoten Iron Range.

With the east Michipicoten Range belong the few small broken bands of iron-bearing rocks occurring west of the Magpie river near Michipicoten Harbor. The northern Michipicoten Huronian, enclosed between two areas of granite, lies between the Magpie river and the western branch of the Pucaswa river. The iron range which it contains is practically a continuation of the eastern range. The western Huronian area, which is separated from the other three by granitic rocks, intrusive in the Huronian, includes three small patches of Huronian rocks, divided by later granite. It lies between Otter Head and Bear river, on the Lake Superior shore, and extends but a short distance north of lake Michi-Biju. Within these is the western belt of iron-bearing rocks.

The eastern Michipicoten Range is much the best known of the iron-bearing belts because it has been carefully studied by Professor Coleman and Professor Willmott, and a report published thereon.[1] This part of the range contains also the working mine—the Helen; the Josephine prospect, and the old mine on Gros Cap worked nearly thirty-five years ago. However, much investigation has to be carried out in parts of this stretch of country before the geological examinations can be said to be complete. The southern Michipicoten Huronian has been examined only in a very hurried way, and no attempt has been made to connect the various bands, known to occur at lake Majinimungshing, cape Choyyé, lake Anjigomi, and elsewhere. On the northern Iron Range the valuable prospects of the Scott, the Frances, and Iron Lake are located, and the belt on which they occur was examined in somewhat slight detail by the writer with Mr. Albert Scott while in the employ of the Algoma Commercial Company, Ltd., in 1902. Dr. Robert Bell also made some investigations on the same belt for the Dominion Geological Survey in 1900.[2] Up to the past summer no connected survey had ever been made of the western range.

During the summer of 1904, the writer, with the assistance of Mr. H. W. Evans of Toronto, carried on geological explorations on both the western and northern ranges, and completed a fair geological survey of the region as far east as the Magpie river. Besides the writer and his assistant the party consisted of a cook and two Indian voyageurs. The party, though small, was a good one, and adequate for the work in hand. Our work was almost entirely by land. While investigating the western range, trips were made inland at intervals of a mile or a little more, crossing the strike of the rocks from the Lake Superior shore to the edge of the granite on the north, and south or north from lake Michi-Biju to the edge of the granite. In the same way traverses were made at short intervals across the northern range from granite to granite. Thus the various bands of iron-bearing rocks which do not appear on the principal watercourses, were discovered and their trend traced across country. In a country broken by rough hills, often separated by swampy valleys, and covered with a dense forest growth, these trips across country day after day were often very arduous, but the work was interesting, and for the most of the summer we were favored with exceptionally fine weather. Generally the trips made inland from the lakes and rivers lasted but one day, going in the morning and returning in the afternoon, often by a new path in order to examine fresh country, but sometimes, as in investigating the country west from Iron lake, it was necessary to tramp for three or four days through the woods without returning to the main camp. When iron-bearing rocks were found as a rule they were of prominent outcrop and easily traceable. When they disappeared beneath muskegs or sand plains, we were sometimes able to trace their continuation by magnetic work, in this following the plan outlined by Professor H. L. Smyth in his pamphlet published by the American Institute of Mining Engineers.[3]

[1] "The Michipicoten Iron Region," Bur. Mines, 11th Rep., pp. 152-185.
[2] See Ann. Rep. Can. Geol. Sur., 1900, pp. 109-121A. [3] Trans. A.I.M.E., Vol. XXVI, 1896, pp. 640-709.

BIBLIOGRAPHY OF THE REGION

For the convenience of those who may be interested in the subject, I give the following list of the literature already published on the Michipicoten Huronian area or on the region adjoining:

Report of the Geological Survey of Canada for 1846-1847, in which Logan describes the conglomerate at the mouth of the Doré river and the sandstones at Cap Choyyon and Cape Gargantua (p. 31). In it, also, Murray has some notes on the Michipicoten river.

Lake Superior, its Physical Character, Vegetation and Animals; Louis Agassiz, 1850.

Report of the Geological Survey of Canada, 1863, in which the Huronian slates at the Doré river are described (p. 52), sandstones of Cape Gargantua considered (p. 82), and the native copper of Cape Gargantua and a deposit of chalcopyrite on Michipicoten bay mentioned (p. 703).

Report of the Geological Survey of Canada, 1866, in which Macfarlane describes the Lake Superior rocks and the occurrence of hematite at Little Gros Cap (p. 130).

Report of the Geological Survey of Canada, 1870-1871, in which Robert Bell describes the Pic and White rivers, and the geology of the surrounding country.

Report of the Geological Survey of Canada, 1875-1876. In this report Robert Bell gives some notes on the Michipicoten river (pp. 331-335).

Report of the Geological Survey of Canada, 1876-1877, in which Robert Bell gives a description of the rocks of the Lake Superior shore from Gros Cap to Cape Gargantua (p. 218).

Report of the Geological Survey of Canada, 1880-1882. Here Dr. Bell gives an account of the rocks of the Michipicoten river and of Dog lake, accompanied by a geological map.

American Geologist, vol. xx., p. 126, etc. An article by Taylor in which he considers Dog lake not an outlet of Lake Superior.

Minnesota Geological and Natural History Survey, vol. xx. Notes by Lawson on the beaches at Dog river.

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"The Michipicoten Huronian Area," A. B. Willmott. The "American Geologist." vol. xxviii., July, 1901, p. 14, etc., in which the eruptive relation of the granites is pointed out and a map given showing the northern iron range.

Report of the Ontario Bureau of Mines, vol. xi., 1902, pp. 152-185. "The Michipicoten Iron Range," by A. P. Coleman and A. B. Willmott. The writers give here a detailed description of the eastern Michipicoten Iron Range.

Journal of the Canadian Mining Institute, vol. vii. "Exploration of the Ontario Iron Ranges," by A. B. Willmott, in which Willmott considers the possibilities or some of the prospects in the Michipicoten Iron Range.

"The Nomenclature of the Lake Superior Formations," by A. B. Willmott. Journal of Geology, vol. ix. (1902). No. 1, p. 67, etc.

Report of Ontario Bureau of Mines, vol. xi., 1902, pp. 70-75, by D. G. Boyd, Inspector. A statistical report of the development in Michipicoten.

PHYSIOGRAPHY OF THE AREA

As has been mentioned, our especial work during the summer of 1904 was an examination of all iron-bearing rocks occurring west of the Magpie river. However, to elucidate, if possible. the problems relating to these rocks, the general geology of the region was studied somewhat in detail and the physiography rather superficially examined.

The topography of the region is one of considerable variety, and that characteristic of the more rugged and less levelled phase of the old Laurentian peneplain of central Canada. Along the shore of Lake Superior high, hummocky, ridge-like hills rise often abruptly from the water's edge. This rugged shore line is interrupted at intervals by broad sand beaches, which break the monotony of the precipitous cliffs. The highest hills, and those of greatest relief above the surrounding country, lie within twelve miles of the Lake Superior shore. Northward, the uneven broken character of the country decreases rather than increases, hills rising to considerable heights above the general level of the country are fewer, and their relief not so great as farther south. Moreover, whereas there is a somewhat rapid rise from the Lake Superior shore of the general level of the country for several miles inland, northward the rise towards the height of land, between the waters of the St. Lawrence and those of Hudson Bay, is so slight as to be scarcely perceptible on the various rivers.

A Region of Hills and Valleys

In general the surface of the country, with its broken ridges, alternating with narrow linear valleys, may be spoken of as hilly. It stands in marked contrast to the surface of the Laurentian plateau north of the Height of Land, which is practically level and devoid of relief. Some distance north from the lake Superior shore the soft Huronian schists are conspicuous physiographically as forming relatively low lands compared with the highlands occupied by the resistant post-Huronian granitic rocks. This difference is not so apparent on the Lake Superior shore, but it is nevertheless evident in places. In going north from Ellen lake, I was particularly struck with this marked physiographic difference between the schists and the granitic rocks. North from Ellen lake for about three miles the rocks consist of granite. Near the northern limit of these rocks the hills abruptly descend to a broad valley four or five miles wide, beyond which the hills rapidly rise again at the border of the northern granitic rocks. The valley contains the northern Michipicoten Huronian synclinonium with its associated iron range.

The highest hills in the Michipicoten area have an altitude of from ten to twelve hundred feet above sea level, and a view from the summit of any of these shows that almost all the other hills rise to the same general height. This uniform altitude indicates, apparently, the existence of a former peneplain, or base-level of erosion, which has been elevated since its formation and is at present undergoing another cycle and being reduced to a second, or possibly third, base-level of erosion by the comparatively rapid action of streams, frost, heat and other atmospheric agencies.

Tip-Top mountain, which Dr. Coleman considers possibly the highest point in the Province of Ontario, lies almost seven miles west of the lake Superior shore and about ten miles north of Otter Head. Its height, as given by Dr. Coleman, is 1,525 feet above lake Superior, or 2,125 feet above sea level.[4] High ridges of hills occur north of Ganley's Harbor, north of Lost lake towards the Pucaswa river, along the eastern branch of the Pucaswa, in the vicinity of Bear Mountain and at various other points.

Within the limits of the northern Michipicoten Huronian area proper the highest hills, which stand out very definitely in this generally low-lying region, consist of eruptive rocks entirely, or at least have a core composed of these rocks, or otherwise

[4] Eighth Rep. Bur. Mines, 1899, p. 142.

they are composed of the resistant quartzose rocks of the iron-bearing formation. The most prominent elevation in this northern part of the Huronian area is that of the Kabenung hills a low range which follows along the northern shore of Kabenung lake for a little over a mile. These hills have probably an altitude above Lake Superior of about 1,200 feet, but the local relief very little exceeds 350 feet, if so great. Heart mountain on the shore of Heart lake, about 250 feet above the surrounding country, and mount Raymond about 300 feet above the waters of Paint lake, near which it is situated, are other conspicuous points on the landscape. These prominent elevations with many others may be spoken of as monadnocks, or hills still standing above the

Fishing village, Michipicoten island.

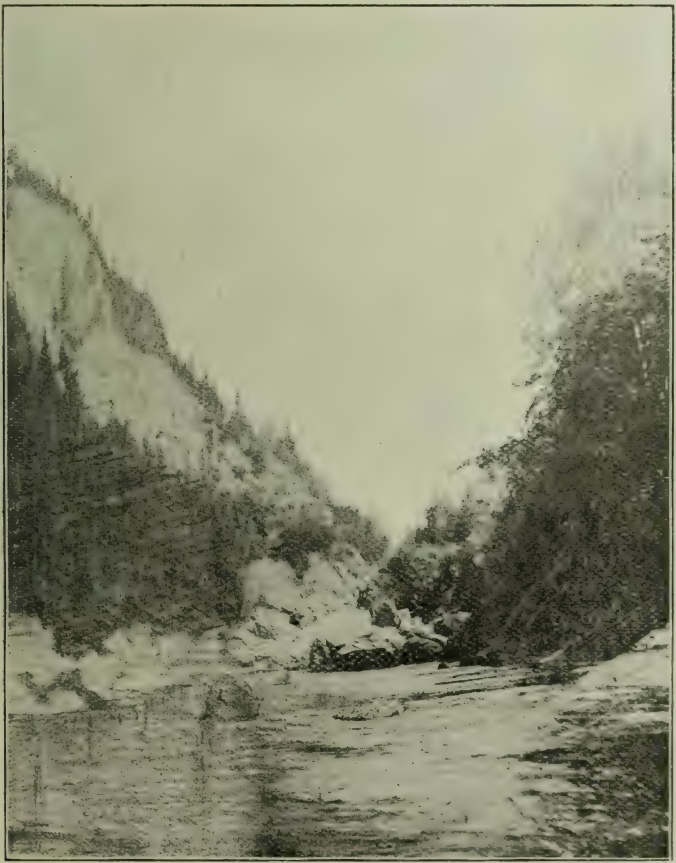
general level, which have been able to resist the long-continued subaerial erosion. In many parts of the country broad lacustrine sandplains, or fairly extensive swamps and muskegs, intervene between the stretches of hilly country and break the usual uneven character of the region.

Rivers of the District

The area is drained by numerous streams and rivulets which thread their way from lake to lake, sometimes almost stagnant for a mile or more, again wild foaming torrents, with rapids over beds of boulders, or waterfalls over cliffs. The largest streams, in the western and northern Huronian areas, are the Pucaswa river and the Dog river, which enter Lake Superior, and the Magpie river, which flows into the Michipicoten river. Other considerable streams flowing into Lake Superior are the Julia river, the Pipe river, the Floating Heart river, the Eagle river, Fall creek, the Bear river, the Little Bear river, and the Doré river. Like all glaciated countries, the region is thickly dotted with lakes varying in size from ponds only a few yards across, up to sheets of water five miles or more in length. These natural reservoirs maintain a fairly uniform flow of water in the various streams, throughout the year, though of course the effects of dry weather or increased rainfall are decidedly observable.

THE PUCASWA

The Pucaswa river was descended[5] by Dr. Coleman from a point about 25 miles above its mouth to Lake Superior in 1898. He describes it as being throughout this distance a particularly difficult stream to navigate, being merely a succession of shallow rapids broken by very short stretches of navigable water. Unlike most of the rivers which enter Lake Superior, there are no lake expansions along its course, at least for 25 miles from its mouth, though there may be, farther towards its source. From a point one-half mile above its mouth the river descends some 55 feet in a distance of less than a quarter of a mile in a roaring cataract, hemmed in, particularly on the north side, by walls of schist, which rise two to three hundred feet above the river bottom. The bed of the stream is filled with immense angular boulders which increase the broken character of the water. Dr. Coleman describes this fall of 55 feet as being the highest fall in the course of the river.

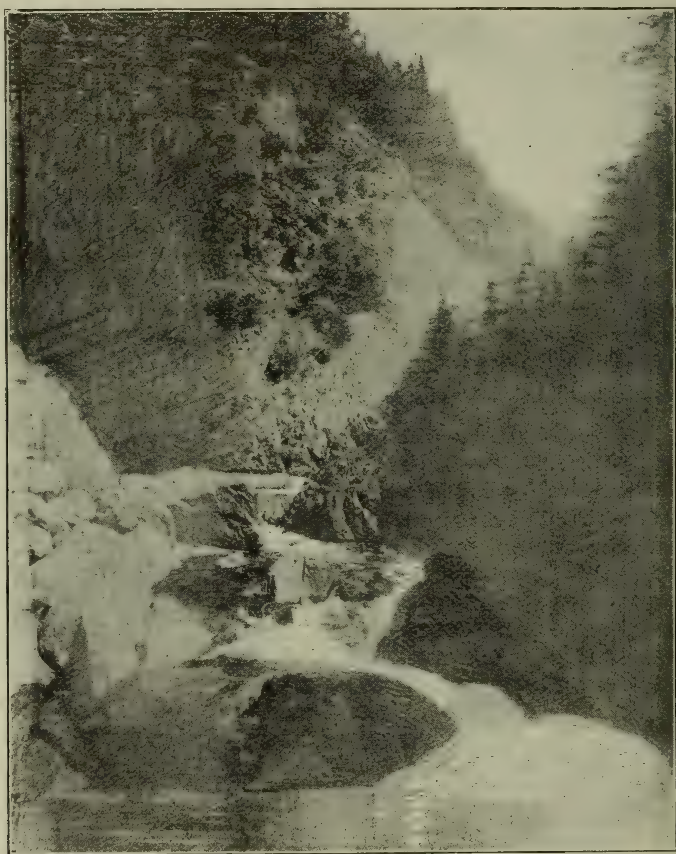


Gorge on the Pucaswa river, near its mouth.

Some five miles above its mouth the main Pucaswa river is joined by the eastern branch, coming from the northeast. This stream is apparently rather more than half the size of the main river. The united stream below the confluence has a width of about fifty yards. The eastern branch rises in a number of small lakes which lie south of Fox lake, near Pokay lake, and about eight miles north of Iron lake. The eastern branch has a length of about thirty miles, and like the main river, is nothing but a

5 Report of Ontario Bureau of Mines 1899, Part II.

succession of shallow rapids and low falls joined by short stretches of more slowly moving water. Neither the main Pucaswa nor its eastern branch is ever now used as a route through the country by the Indians, though it is said that they were navigated in summer some twenty years ago or more by a family who bore the name of Pucaswa from the stream on which they lived, and who were all drowned in crossing to Michipicoten island early in spring. There is a fairly good portage-trail on the left bank of the stream, past the falls near Lake Superior, but this is apparently the only sign of the former use of the river.



Gorge on Pucaswa river, near mouth.

A small stream some ten miles in length, which enters near or at Otter Cove, rises near the Pucaswa river, and is still used by the Indians in entering the country. The stream joins together a number of small expansions, the portages between which are short, and there is only one long carry of about two miles from Otter Cove to the first lakelet.

Some two and a half miles southeast of the mouth of the Pucaswa, the Julia river enters Lake Superior. It is a small rapid stream, only six or seven miles in length, which rises in some small lakes and ponds to the northeast of its mouth. The Pipe river, which enters Lake Superior about seven miles southeast of the Julia river, has a length of about six miles, and drains a number of lakes one-half mile or more in length. These lakes form part of the canoe route, from Red Sucker harbor to the David lakes, near the Pucaswa river.

Floating Heart river, which flows into Lake Superior about a mile and a half east of Ganley's harbor, is the largest stream between the Dog river and the Pucaswa. It drains Floating Heart lake, Lost lake, and the lakes lying to the southwest of lake Michi-Biju. Some of these lakes are on the route between the mouth of the Ghost river, via Little Trout lake, to lake Michi-Biju.

Eagle river flows into Lake Superior just west of the high cliffs known as "Les Equerres,"[6] and about eight miles west of the mouth of the Dog. The river drains Cameron lake and other lakes south of lake Michi-Biju, and is not navigable. About a mile above its mouth are falls of great beauty, which occur in a succession of three jumps close together, each of about thirty feet. Fall brook is a small rapid stream, flowing into Lake Superior about three miles west of the Dog river.

DOG RIVER

The Dog river, which has an average width of rather less than seventy-five yards near its mouth, is navigable from its headwaters to Lake Superior, though broken by considerable stretches of rapids. It may be said to be formed by the union of several small streams which enter Obatonga lake, an irregular, marshy sheet of water lying some twenty-seven miles north of Lake Superior. Leaving Obatonga lake, after a course of about one-half mile, on which there is a rapid which has to be portaged, the river enters Knife lake. This lake, which is some three miles long, the river leaves at its southern end, and after a course of less than a mile, enters Heart lake. There are two portages, the most northern of which is only a lift between Knife lake and lake George. Heart lake is a narrow sheet of water about a mile and a half long. From its outlet to Lake Superior the Dog river is broken by many rapids and falls. These are short and unimportant, and do not seriously impede navigation as far as the mouth of the stream from Ekinu lake, but south from this point their frequency and length form a great impediment, and render the route by Ekinu lake, Mud lake and lake Michi-Biju the preferable one to Lake Suprerior.

The most important tributary of the Dog river, from the west, is Iron creek, which enters the river about three miles below Heart lake, and drains Iron lake, Little Beaver lake, Sigami lake, Nichols lake, and others. Joining the Dog river from the east there are three principal tributaries, the Crayfish river, Paint creek and Mountain river. The Crayfish river enters the Dog river between Knife and Heart lakes, and drains the important chain of lakes which includes Kabenung lake, Lac Poisson Gris, and Muskrat lake. Paint creek flows into the Dog river, some two miles below Heart lake. It is navigable for three miles above its mouth as far as the Frances mine, and drains Paint lake, Sage lake, Skunk lake, and other lakes lying to the south of Sage lake. The Mountain river flows into the Dog about five miles above its mouth. It is a rapid stream, seldom used by the Indians, and drains Jimmy Kash and adjoining lakes.

The Mountain Ash river, the Bear river, and the Little Bear river, are three small and unimportant streams which drain the rocky interior between the Dog river and the Doré river. The Doré river is formed by the union of a number of small streams which rise in lakes south of Muskrat lake and from eighteen to twenty miles north of Lake Superior. Some three miles from Lake Superior is Doré lake, an almost round body of water about two miles from north to south. Below Doré lake a continuous succession of falls and rapids render navigation impossible. Above Doré lake for some three or four miles the travelling on the river is easy and without serious impediment. Northward, however, rapid after rapid, unrelieved by long stretches of smooth water, make it a very difficult route to Sage lake, though it is sometimes followed by the Indians, and was descended by Mr. Evans late the past autumn.

6 Pronounced by the natives *"DesEcöres."*

THE MAGPIE RIVER

The Magpie river rises in Esnagami lake, north of the Canadian Pacific railway, and after a course of some fifty miles, it enters Michipicoten river about three-quarters of a mile from Lake Superior. Near its mouth its usual width is from fifty to eighty yards. Southward from the Chute which impedes navigation on the river at about three and a half miles south of McKinnon's bridge, the river is broken by long and almost continuous stretches of shallow rapids. These are not sufficiently large to prevent travelling by canoe, but are often difficult to pass in low water though almost obliterated in seasons of flood. During this stretch there are three falls of magnitude. One is at the mouth of the river, and has a drop of 113 feet. The second series of falls have a drop of 73 feet, and break the river some two miles above its mouth, and the third, the Steep Hill falls, with a drop of 60 feet, are about sixteen miles from the mouth. Above the Chute long stretches of smooth water, often lake-like, are broken by small and easily passed rapids as fas as the Portage falls some three miles above McKinnon's bridge. For six miles above the Portage falls the river meanders through a sand-plain and no rapids occur. Then the smooth water is broken by over two miles of rapids Kabetachewan or Long rapids. North of Long rapids extensive stretches of navigable water are interrupted by only short rapids and falls as far as the Canadian Pacific railway—a distance of about eight miles.

The Magpie river has two important tributaries from the west—Evans creek and Catfish creek. Evans creek drains the chain of lakes east of the Grand Portage between the waters of the Magpie and Dog rivers. These lakes include lake Kapinchigama, Lund lake, lake Pasho-scoota, Godon lake and Pyrrhotite lake. Catfish creek rises in a number of small lakes lying south of lake Maguire, and enters the Magpie river about ten miles above its mouth. Some three miles up its course from the Magpie is Catfish lake, an expanse of water some two miles in length. Below Catfish lake the river is a succession of shallow rapids, and is too much filled with driftwood to be navigable. It has an average width of about forty feet. Above Catfish lake for some three miles there is no serious impediment to navigation, although log jams and short rapids break its course at intervals. Higher up the river, however, rapid after rapid. all of which are shallow, render the stream a very difficult one by which to travel. It is occasionally used by the Indians in high water, and was descended by the writer during the autumn of 1904.

It will be seen from this brief account that the rivers of Michipicoten are rapid streams, all of which have a large average drop per mile. In general, however, the average descent per mile increases towards Lake Superior, and in the lower part is often so great as to preclude navigation altogether, whereas in the upper stretches lake expansion, or slack river water, render that part of the various streams quite suitable for travel. The Magpie from the Canadian Pacific railway to Lake Superior has a descent of some 550 feet, and of this quite 190 feet occurs within the last two miles and a half. Similarly the Dog river has a descent from McMaster lake (in which one of its headwater streams rises) to Lake Superior of about 780 feet, and of this 175 feet occurs within the last two miles. The main branch of the Pucaswa, according to Dr. Coleman,[7] has a descent of 575 feet from a point some 25 miles up its course to Lake Superior.

Lakes of Michipicoten

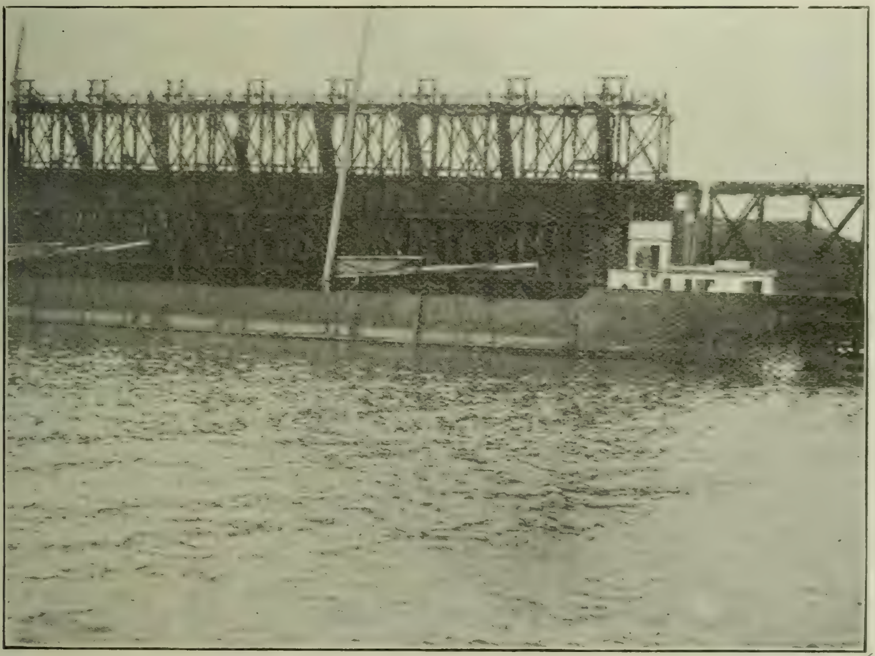
As has already been mentioned, lakes are common physical features in Michipicoten. They are of two types—those which occupy rock basins, the outlet of which is dammed by rock ledges or by moraines, and those which fill holes in the drift formerly occupied by masses of ice, left by the retreating ice sheet. Of these two classes the first is much the most important, and to it belong all the larger lakes in the region, including the river expansions. To the second class belong the numerous

[7] Eighth Rep. Bur. Mines, 1899, p. 138.

ponds, seldom exceeding one-half mile in length, which dot the few level stretches in the wooded interior of the country.

The largest lake in the Michipicoten area west of the Magpie is Kabenung lake, a sheet of water some seven miles in length, and with a maximum width of about two miles. It is of exceedingly irregular outline, like all the lakes in Michipicoten, and is divided into two parts by a narrows a few yards wide and less than one-eighth of a mile long. The surface area of its water, owing to the numerous islands which occur within it, is much smaller than most lakes of its dimensions. After Kabenung lake the lakes next in size are lake Michi-Biju, and Michi lake, which are joined to each other by a small stream about seventy-five yards long. Michi-Biju lake is some two and a quarter miles long by a mile and a quarter wide, while Michi lake is about a mile and a half long by three-quarters of a mile wide. They are both beautifully clear-watered lakes with very few islands.

Compared with the country north of the Height of Land swamps and muskegs are comparatively rare, but often the smaller lakes especially, and even some lakes of



Dock, Michipicoten.

fair size, are surrounded by wide borders of marsh. Again, the lakes in the marsh may have become quite insignificant or have disappeared altogether, and a wide area of grass-covered meadow be all that remains of a former extensive body of water. Most of the lakes are shallow, and there are few which exceed thirty or forty feet in depth. Some are so shallow, such as Mud lake, near lake Michi-Biju, and the Big Marsh, near lake Maguire, that it is almost impossible to get through them by canoe, especially when towards the close of the short season, their surface is choked with patomogetons and pond lilies which grow in the decaying product of their own decomposition

The water in most of the Michipicoten lakes is brownish in color, and not clear whitish water. There are two rather remarkable ponds on the trail from Dog river to Iron lake. These are Spring lake and Clearwater lake. They are both small, but are comparatively deep depressions in the glacial drift. The upper pond, Clearwater lake, is held in by a narrow moraine which follows its eastern border. Their water

is of remarkable transparency, and is possibly lower in temperature during the summer than that of the surrounding lakes. The lower pond, Spring lake, has a bottom composed of rounded cobbles of various sizes, coated with a whitish material, probably in great part vegetable, which enhances the bluish-white coloring of the water. The outlet of the two ponds is by Clear creek, which enters the Dog river some four miles below the mouth of Iron creek. The lakes are supposed by the Indians to be springs, and though I could find no direct evidence in favor of this hypothesis, the large size of the stream which drains them compared with the small size of the entering streamlets seems to give proof to the theory.

Effects of Glacial Action

The Michipicoten region is one of pronounced glaciation, showing on the whole greater denudation than deposition. The rocky hills exhibit the mammillated contours characteristic of regions which have been invaded by the ice sheets, and everywhere the surface of the solid rock is grooved and striated. The glacial striæ vary somewhat in direction throughout the area. On the Lake Superior shore near the Dog river, the usual trend is from S. 10° W. to S. 15° W., but towards the interior, especially in the northeastern part, the direction is more southwestward. The wide sandplains which are of frequent occurrence in Michipicoten, may represent the deposits formed by the waters of Lake Superior when it stood at a higher level, or possibly they are at least in part the sediments laid down by lakes formed in close contact with the retreating continental ice sheet. Numerous boulders scattered irregularly over hill and valley are further evidence of the work of the glaciers. Well-marked moraines of various kinds are common, and often greatly influence the drainage. Somewhat remarkable are the immense irregular masses of coarse moraine stuff which occur on the Mountain Portage between Pokay and McMaster lake, described by Dr. Robert Bell.[8] The elevated beaches marking the former level of the water, which fringe the present margin of Lake Superior, often for miles into the interior and at considerable heights above the present level of the water, have already been described by various writers.[9] Remarkable terraces occur near the lake Superior shore, extending from a point three miles east of the mouth of the Dog river to a short distance west of that stream. They can be seen to best advantage some two or three miles out in the lake. They are composed of fine gravel and sand, and are distinct and clear cut in outline. Terraces may also be observed in the lower and upper parts of the Dog river, and on the Pucaswa river.

As the Michipicoten district has only so recently been inhabited by white men, it contains few evidences of white occupation. On the western side of the Magpie there is a small settlement at Michipicoten Harbor, where the ore docks are situated, and on the eastern side of the river there are the settlements of Michipicoten River, of Wawa City, and of the Helen Mine. Formerly there were small settlements at the Frances mine and at Iron lake, to the west of the Magpie, but these are at present deserted. The line of the Algoma Central railway is at present built as far as the Josephine mine, with a spur to the Helen mine. There is a good road from Michipicoten river to Wawa City, and to the railway at Wawa station, also a road to the Grace mine, to Anjigomi lake, and to other points near Michipicoten river, built before the cessation of work on the Algoma Central railway. The old tote road to Ryerson, built at the time of the construction of the Canadian Pacific railway, was cleared out and improved by the Lake Superior Power Company in 1900, and though now practically disused, is still in pretty good repair. It has been chiefly used in winter, though there is no reason why it could not be made a good summer route. It lies on the eastern side of the Magpie as far as MacKinnon's bridge, where it crosses the river and follows close to the western border of the river for some twelve miles, when

8 Summary Report Geol. Sur. Can., 1900, p. 120.

9 Geol. Nat. Hist. Sur. Minn., 20th Annual Report. Eighth Rep. of Ontario Bureau of Mines, 1899, p. 153, etc.

it diverges and strikes across country to Ryerson on the Canadian Pacific railway. There are old winter tote roads from Michipicoten Harbor to the Frances mine, and from the Frances mine toward White River station, but these are scarcely recognizable as highways through the country in summer. The proposed extension of the Algoma Central railway crosses the Magpie a mile or two below McKinnon's bridge and follows south of the chain of lakes which stretches between the Magpie river and Dog river. It crosses the latter below Heart lake and follows to the west of that body of water and of Knife lake, northward.

In fact, save for a very small section of the country the sole means of travel through the region in summer is by the long used Indian canoe routes along the rivers or by the chains of lakes and portages; while in winter the entire area, save at the few isolated settlements, is given over to the Ojibway hunters who still roam and hunt throughout the district.

CANOE ROUTES

For the convenience of travellers who may in future visit the Michipicoten country west of the Magpie river, I shall here give a brief description of the principal routes of travel throughout the area. The route via the Magpie river from Grassett to Lake Superior,[10] the route from White River station via White and Dog rivers to Lake Superior,[11] and the route via Bremner river and Pucaswa river to Lake Superior,[11] have already been described, and it is unnecessary for me here to consider them in detail.

Lake Superior to Frances Mine

The canoe route from Lake Superior to the Frances mine leaves the shore just behind the settlement of Michipicoten Harbor. The trail leads for some two and three quarter miles over low hills, through a wide swamp and around several small ponds which may or may not be utilized, depending on the state of the water, to Doré lake. The Doré river is ascended for some three miles when a portage leaves the stream on the right bank and stretches across the low hills near Eagle mountain for about two miles to the stream which flows out of Molybdenite lake. In high water this stream may be used, but as a rule loads are carried through to the lake. Molybdenite lake is an irregular body of water a little over a mile long, which the route leaves at the north end. Nine lakes, all small, succeed Molybdenite lake. They are separated by short portages varying in length from a few hundred yards to over half a mile. From the most northern of these lakes a good trail of five miles leads to Kash lake. Kash lake, or perhaps more correctly Jimmy Kash lake, is a crooked sheet of water over three miles long. A small stream flows into its northern end from lake Isabella—a round pond about a quarter of a mile in every direction. From the northwest corner of lake Isabella a good portage of less than a mile and a half leads to Lac la Plonge, whence another good path a little over three-quarters of a mile long runs through the woods to the Frances mine. The route from Michipicoten Harbor to the Frances is about twenty-seven miles long, and of this less than half the distance is by water.

Frances Mine to Dog River

There are two routes from the Frances mine to the Dog river—one by Paint creek, which is descended from Rawlinson pond, on which the Frances is situated, to the Dog river, which it enters about two miles southwest of Heart lake. This route is a good one in high water, as no portages are necessary, but in low water it is not easy, and several short carries have to be made. The other route, and the one more usually followed in going to or from White River station, leaves Paint creek about a quarter of a mile below Rawlinson pond, and strikes northwestward by an excellent

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10 Seventh Rep. Bur. Mines, 1897, pp. 184 ff 11 Eighth Rep. Bur. Mines, 1899, p. 136, etc.

portage of about one mile to the Dog river. In high water the portage need not be so long, and the canoe may be put into the water at about three-quarters of a mile from Paint creek, but when this is done a small carry has to be made in going up stream on the right bank, which is avoided by the longer portage across the river. The portage reaches the Dog river in the big bend of the stream, a quarter of a mile below the first small rapid below Heart lake. In descending the Dog river without going to the Frances mine, the entrance of the portage trail to the Frances is not passed, as the portage to avoid the rapids in the big bend leaves just across the bay from the small rapid above mentioned, and on the opposite side of the river from the Frances trail.

Frances Mine to Iron Lake

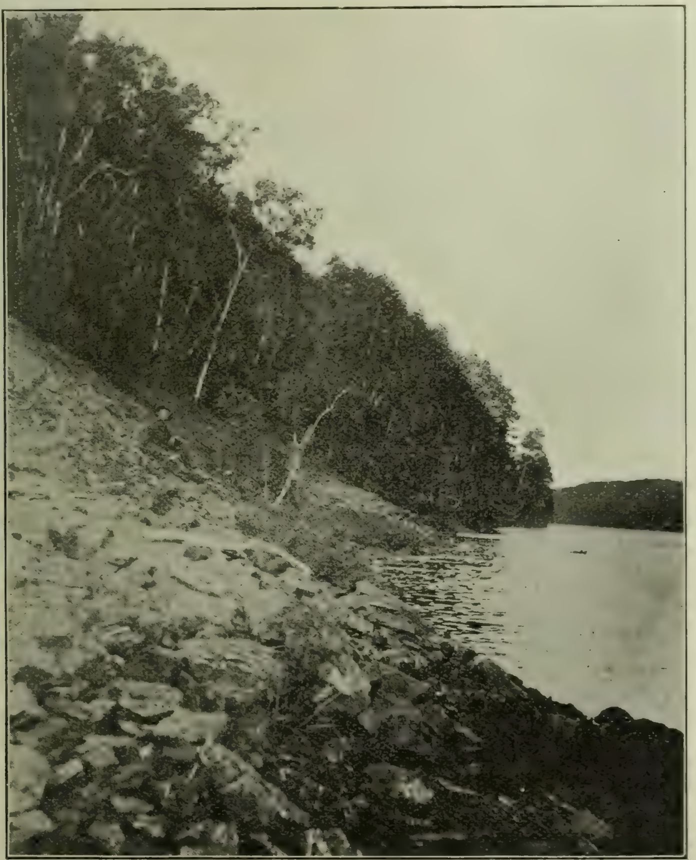
The route from the Frances mine to Iron lake is in part by the Dog river. Just below the mouth of Paint creek is the small chute in the Dog river known as the Rapid of the Drowned. Immediately above the first rapid below this chute and at rather less than half a mile below the Rapid of the Drowned, the portage trail leaves the western bank. There are three portages, all in excellent shape, with good paths

Iron lake.

across the sandplains through the Banksian pine barrens. The first portage is a little more than one-half mile long, and leads into Pitch Pine lake. The outlet from Pitch Pine lake into Iron creek is often shallow, and a short lift is sometimes made here into Iron creek. Iron creek is ascended for less than a hundred yards when the second portage leaves from a small swampy bay on the west side. The second portage, less than one-half mile long, conducts the traveller into a small clear-watered pond which is crossed, and the third portage taken. This portage is said to be the best trail in Michipicoten district, and is so level that we took our loads across it in a wheelbarrow. It is about three-quarters of a mile long, and leads into Iron creek rather more than a mile below the lake of the same name.

Iron lake is a beautiful sheet of water, somewhat less than two miles long and roughly stellate in shape, having five pronounced arms—two opening to the east and

three to the west. Iron creek flows out by the southeastern bay. From the northeastern bay a short canoe route leads by Sigami creek and Sigami lake to Nichols lake. From the southwestern bay a route of three portages, divided by two small ponds—Cleawater lake and Spring lake, may be taken to the Dog river, which it reaches about four miles and a half below the entrance of the other route to Iron lake, just described. This is the usual path to Iron lake taken by voyageurs coming up the Dog river from lake Michi-Biju. From the middle western bay known as Minnesota bay, a trail leads a little south of west. For the first two miles, as far as Bole lake, the path is a good one, but beyond Bole lake it is not easy to follow, though it is traceable with some difficulty as far as the eastern branch of the Pucaswa river,



Iron lake.

about nine miles west of Iron lake, and is said by the Indians to lead to the shore of Lake Superior. From the foot of the northwestern bay a trail leads to several small lakes, and at the point where Iron creek enters Iron lake, a short and easy route leads up by that creek and its expansions to Little Beaver lake.

Dog River to Lake Michi=biju

The route from Dog river to lake Michi-Biju is now seldom used. It leaves the Dog river at the mouth of the small brook entering the main river from the west about a mile and a half below the point where the lower route leaves the Dog river for the southwestern bay of Iron lake. A short distance up this brook a carry is

made past a fall of some ninety feet, over a steep hill into Ekinu lake—a narrow sheet of water rather more than two miles long. From its southern end a portage a mile long leads through a new brulé to Mud lake. Mud lake, which might more correctly be called a marsh, so difficult is it to dig one's way through it by canoe in midsummer, is about three-quarters of a mile long. At its southern end a choice of routes is open to the traveller. One to the southwest leads directly by a portage of two and a quarter miles to Michi lake; the other is much more roundabout, though with shorter portages and is by several small lakes and streams to the Goosefeather river, which is ascended to Michi lake.

Lake Michi-biju to Lake Superior

There are two routes from lake Michi-Biju to Lake Superior, and neither of these is good or much used. One leaves a bay at the entrance of a small stream and leads by a number of small lakes connected by portages, to the Floating Heart river. This stream, with its expansions, is descended to a little below the foot of Floating Heart lake, where a portage leads through a gorge to Cameron lake. From the southern end of Cameron lake the route leads back into the river, which is descended for about one-half mile, when the portage leaves its southern bank. The trail thence is by a number of small lakes to Lake Superior. The other route, and the one more generally used, leaves Michi lake by a small stream which is descended for a little more than half a mile, with several short carries, to its junction with the Goosefeather river, which is ascended for about two miles. For this distance the creek is shallow in low water, but as a rule only one portage, and that a short one past a log jam, is necessary in high water. From Goosefeather river a chain of eight small lakes and nine portages leads to Lake Superior, the route entering Dog River harbor. Only two of these portages are long—the first and fourth from Lake Superior, the former being two and three-quarters miles long, and the latter rather less than a mile and a quarter.

Frances Lake to Lake Kabenung

There are two routes from the Frances mine to Kabenung lake. One is by the Dog river to Heart lake. From the north end of Heart lake the portage taken is not that one by lake George, but along the Dog river itself. The Crayfish river enters the Dog river between Knife lake and Heart lake, and this stream is ascended about a quarter of a mile to Crayfish lake. From the foot of a long narrow bay which opens to the east of Crayfish lake, a good portage of a little over half a mile leads into Kabenung lake. The route enters the northwestern part of Kabenung lake, about one mile and a half west of the narrows. In high water in going from Kabenung lake to the Dog river, the Crayfish river, which is rather rapid, is sometimes used. The other route from the Frances mine to Kabenung lake is taken from Paint creek just above Rawlinson pond. Here a portage a little over a mile long leads to Paint lake. Paint lake and Sage lake together have a length of about three miles and a half, but there is a short stretch of river in between the two on which two unimportant rapids occur. The eastern end of Sage lake is divided into two bays. The route from Paint lake by several lakes and portages to the headwaters of the Doré river leaves by the southern bay, while from a point about half way along the shore of the northern bay a very short portage leads into Skunk lake. Skunk lake is a small clear-watered pond a little more than half a mile long. A short portage leaves it from the western bay at its north end, and falls into the southern part of Western Kabenung lake just at the foot of Big island.

Lake Kabenung to Magpie River

The route usually followed from Kabenung lake to the Magpie river leaves the former body of water by a small stream, known as Elmo creek, which flows into the eastern side of a bay on the southern side of Eastern Kabenung lake about a mile

and a half east of the Narrows. The stream is ascended for a few hundred yards into lake Elmo. From lake Elmo to Lac Poisson Gris the stream or its small expansions are followed, five short portages being necessary. The route leaves Lac Poisson Gris about half way along the southern shore of the eastern bay, and a short carry is made to Muskrat lake. Muskrat lake is a ragged sheet of water filled with islands, and some two miles from north to south. The route does not, however, follow the main arm; and soon after, leaving the portage from Lac Poisson Gris, turns to the west through a narrow channel into a round bay to the entrance of Elmo creek, where a portage is made into lake Alabama. Lake Alabama consists of two ponds joined together by a narrow, sluggish channel. A short portage leaves the northeastern part of the lake, and leads into Fishhook lake. This the route leaves near its southern end by a carry into Elmo creek, here sluggish and meandering, through a wide meadow. This is ascended for less than half a mile, with a short lift necessary in low water, as far as the entrance to the Grand Portage, which leaves the creek here dwindled to very small proportions, on its southern side. From this point there is an alternate route to Kabenung lake from the one which I have just described which goes by Princess lake and several small beaver ponds lying north of it to Brant lake, whence the route is past Scott's Camps to Lonely lake, and thence by a long portage of nearly two miles, broken by two small ponds, to the eastern end of Kabenung lake.

The Grand Portage

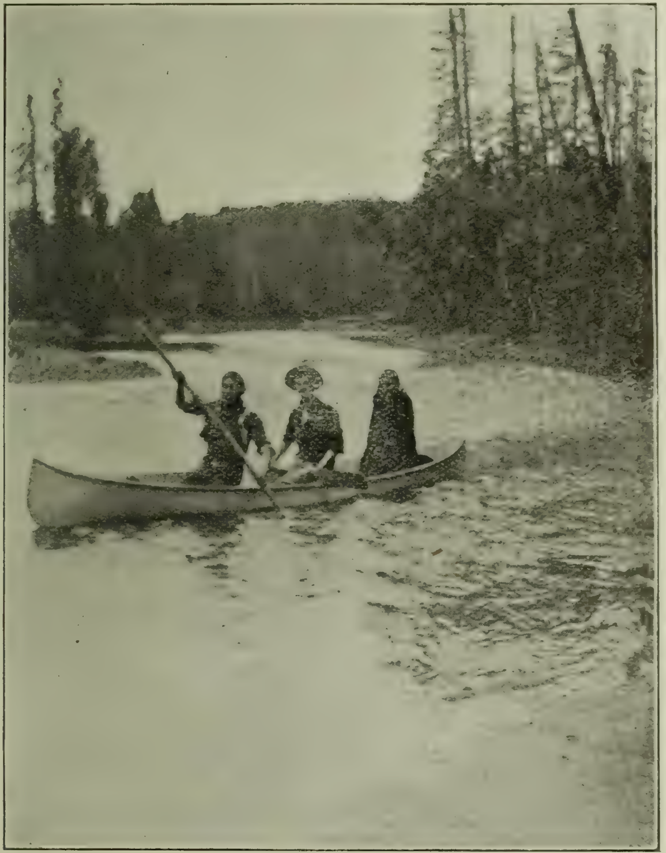
The Grand Portage is some three and a half miles across, but this distance is broken by three small ponds which may or may not be made use of by the traveller. On the eastern side of the Grand Portage is the Big Marsh, a very shallow pond less than three-quarters of a mile in length, lying in a wide grassy meadow. A portage of less than half a mile leads from the Big Marsh into lake Maguire along the shore of Evans creek, which flows to the Magpie. Lake Maguire has a length of a little less than a mile, and is irregular in outline. From its eastern end three routes leave, and all lead to the Magpie. One starts from a small bay near the centre of the eastern part and connects lake Maguire with the headwaters of Catfish creek. This route is very seldom used and has already been briefly described. The route usually followed by the Indians from lake Maguire leaves the eastern part in a bay to the north, close to the outlet of the river, where a short portage is made over flat rocks into lake Kapinchigama. The general form of lake Kapinchigama is that of a cross, the main arm lying north and south. The route leaves the eastern arm on the north side, whence a portage of a few hundred yards leads to a small round pond. From this pond another portage leads into Lund lake. From the eastern end of Lund lake which is three-quarters of a mile long, a short portage is made into lake Pasho-Scoota. From a shallow bay in the extreme eastern part of lake Pasho-Scoota an Indian hunting route leads northeast to several good-sized lakes and ponds, and almost from the same point another portage trail runs south for half a mile over rolling rocky ground and through a beaver marsh to Godon lake. From the southern end of Godon lake a sluggish stream is descended for less than a quarter of a mile, whence a portage is made into the northern end of Pyrrhotite lake. Pyrrhotite lake has two bays opening to the west. A small creek flows into the most northern of these bays, and from its mouth a shorter and more direct route than the one just described leads to lake Maguire. The first portage which leaves lake Maguire about half-way between the entrance of the trail to Catfish creek and the outlet of the lake, runs through a muskeg for about half a mile into Island lake. This is a small round pond one-half mile in every direction. From its eastern end a carry is made on the southern side of a small creek into Clearwater lake. Clearwater lake, a little less than three-quarters of a mile long, is left at its eastern end, whence a portage follows along the eastern side of the creek into a small muskeg pond. From this pond the portage leads close to the north shore of the creek for half a mile into a small expansion of the stream close to Pyrrhotite lake. In high water no further portage is necessary, but when the

water is low, a carry of a few steps has to be made just at the entrance into Pyrrhotite lake. On this route the portages are much better cut out than on the northern and longer path; but it is seldom uesd by the Indians. From Pyrrhotite lake the route to the Magpie leaves by a short portage on the western side of a small stream entering at the southeastern corner. This portage leads into lake Marian. Lake Marian consists of two ponds, each about half a mile long, joined together by a narrows, where the portage is usually made excepting in very high water. The route does not go to the extreme south of lake Marian, but leaves on the east side by a narrow sluggish channel, just south of the narrows. This channel soon expands into a round pond, from the south side of which a portage of about seventy-five yards leads to Punk lake. From the southeastern end of Punk lake three portages, separated by two ponds, lead to the Magpie river, the first one from Punk lake being about three-quarters of a mile long, the next one half mile, and the last into the Magpie, a little over a mile. The route reaches the Magpie just below a high ridge of diabase, which here traverses the river and about a mile above McKinnon's bridge.

Missanabie to Magpie River

In entering the country which we had to examine during the past season, we came in from Missanabie station by a route seldom followed; and although it lies on the east side of the Magpie river, and is hence outside of the limits of this report, still for the benefit of those who may attempt to follow it in future it may be well to give a short account of it here. The route leaves Dog lake, on which Missanabie station is situated, about nine miles from the railway, from the foot of the southwestern bay, just opposite the deserted houses of the Emily mine. The first portage leads for three miles over a rough, rocky country, for the most part burnt clean, into Jackfish lake. Jackfish lake is of extremely irregular shape, having long arms stretching in every direction. It is about three and a half miles long, but is not followed to its extreme eastern end. A stream is entered on the northern side about two and a half miles from the portage to Dog lake, and is ascended for about a mile through its various meanderings into Qua-ka-geshick lake, a small lake a little more than a mile in length. The route leaves it about half way down its northern side by a portage of half a mile which leads into Twin lake. Twin lake consists in reality of two small lakes joined together by a stream about three yards long, where a rapid occurs and a portage is necessary. The route leaves the western end of the most northern of the lakes, and a short portage is made across a lake terrace into a small pond. From the north end of this pond a short portage leads into a second pond, from which a trail if less than half a mile leads across the hills into Goodreau lake. This body of water is extremely crooked and ragged in shape. From a small southwestern bay a route may be followed to the headwaters of McVeigh creek, and from its northwestern bay the route goes to the Magpie. The portages up to this point are fairly good, but from this point on are almost impossible to trace. Leaving Godreau lake, three shallow ponds, each rather less than half a mile long, follow, separated by short portages. From the third pond a small stream is descended for about half a mile, and a portage taken on the northern bank at the head of a series of falls. The portage leads over rough rocky hills, through a treeless country for half a mile, and falls into a small grassy-bordered pond known as Paddy's lake. The next portage leaves just across from the last, and is made into lake Kamshogocka. Lake Kamshogocka is the only lake of any size on the route other than Jackfish lake. Its shores are high and rocky, and the scenery would be very pretty were it not for the absence of green timber. The lake is about one and three-quarters miles long, and lies about north and south. The route enters by a round bay on the eastern side, separated from the main lake by a narrows, and leaves at the north end by Cradle creek, formed by the union of several brooks entering lake Kamshogocka. Cradle creek, a small stream of about ten yards average width, flows into the Magpie near the point where that river, after a course of some eight miles southward from Grasett

station turns to the west. The distance from lake Kamshogocka to the Magpie river by Cradle creek is about four miles, and the general direction of the stream is about north. Eight short portages are necessary between the lake and the river, none of which are long. In general the route from Dog lake to the Magpie river is a poor one, and is only suitable for small canoes, and even then when lightly loaded.



Canoe on Magpie river.

GENERAL CONDITIONS IN THE REGION

In general the forest on the north shore of Lake Superior is northern in character and differs materially from that of southern Ontario. It is characteristically evergreen rather than deciduous. Unlike the forest growth on the rich clay river flats bordering the various streams north of the Height of Land, for the most part it is not healthy and luxuriant, but growing on a rocky or light sandy soil, and exposed to the force of almost unceasing winds from Lake Superior, it is usual to find the trees of a stunted, knotty character.

The Forest Resources

The principal forest trees are white spruce (*picea alba*) black spruce (*picea nigra*) tamarack (*larix Americana*), cedar (*thuya occidentalis*), balsam (*abies balsamea*), white birch (*betula papyrifera*), aspen poplar (*populus tremuioides*), balsam poplar (*populus balsamlfera*), and Banksian pine (*pinus banksiana.*) Sugar maple (*acer saccharum*), soft maple (*acer rubrum*), swamp elm (*ulmus Americana*), black ash

(*fraxinus sambucifolia*), yellow birch (*betula lutea*), white pine (*pinus strobus*), and red pine (*pinus resinosa*), all occur in the Michipicoten area, but are not predominating forest trees. Probably the best red and white pine seen was on Iron lake, and though there are small patches of these valuable trees throughout the area, it is never in large enough quantity nor sufficiently good to be valuable as timber. Stunted red maple may be seen on nearly all the high hills, but sugar maple is not so commonly distributed. Clumps of fairly large trees occur, however, in shallow hollows between the hills at several points on the west side of the Magpie, notably just north of Maple lake, about a mile west of David's lakes, and near Maiden's Leap mountain on the south shore of lake Michi-Biju.

Very little of the timber in the area will be useful for lumber, though there is much that will be valuable as pulp wood. The broad sand-plain which borders the Pucaswa river near its mouth is covered with a healthy growth of spruce, birch and poplar. There is a stretch of very good forest westward from Cameron lake north of Lost lake to Maple lake, and also southward and southwestward from Iron lake. The timber around Kabenung lake and across the Grand Portage is poor, though it appears to improve in character southward and southeastward to the Magpie river.

The common shrubs of the area include many species of willow (*salix*), mountain maple (*acer Pennsylvanicum*), white alder (*alnus incana*), green alder (*alnus viridis*), red cherry (*prunus Pennsylvanica*), choke cherry (*prunus Virginiana*), mountain ash (*pyrus Americana*), service berry (*amelanchier Canadensis*), hazel (*corylus Americana*), and juniper (*juniperus communis*). Hawthorn (*cratægus coccinea*) is rare, but is found at several points.

Like most parts of Northern Ontario, great stretches of the Michipicoten area have been swept of their timber by forest fires which devastate parts of the country almost every year. It is unfortunate that nothing can be done to lessen, if not stop entirely these annual ravages, because though the timber of the Michipicoten is not as valuable as that of other more favored localities, still much of it will be required for local use by the various mines, which I feel confident will in the future open along the iron ranges, even if comparatively little is fit for export. By far the largest burned area is the immense stretch which extends south from the Canadian Pacific railway. The northern boundary of this fire-stripped tract may be said to be an irregular line extending from a point about two miles north of Iron lake on the west to a point on the Magpie river about three miles north of McKinnon's bridge. On the east, south of McKinnon's bridge, there are wide areas along both sides of the Magpie deprived of their timber as far south as the mouth of Catfish creek. There are patches of brulé on Iron lake, at the southern end of Mud lake, and westward to Miron lake, around the Frances mine, at the western end of Paint lake, on Heart lake, on Kabenung lake, and at many other places. Most of these areas were apparently burnt over some years ago, as already in many places a healthy growth of young trees has started.

Soil and Climate

Compared with the rich clay soil found north of the Height of Land, the shallow soil on the rocky hills of Michipicoten, and the sand- or gravel-filled valleys, are from a standpoint of fertility in marked contrast. In fact, very little of the land of the Michipicoten area seems fit for general cultivation, though I believe if the timber were removed, much of it would be fit for pasturage. Many of the wide dried-up marshes surrounding shrunken lakes, or occupying the position of former lakes, are covered in midsummer with as plendid growth of wild grass, very suitable for cattle, and in many of the more completely burnt areas fine grass crops may be seen growing in the timber denuded country. There is a small patch of fertile land lying along the shores of a small creek entering Otter Cove; again, some good stretches occur along the Floating Heart river near Lost lake, and at various other places, but none of these are of any size. The summer is apparently hardly long or warm enough to grow wheat, though oats seem to ripen and potatoes usually are a successful crop where tried.

The climate of the Michipicoten area is for the most part that of the whole of the north shore of lake Superior. In winter the snowfall is heavy, and in summer the rainfall is generally great. In winter low temperatures are common (as will be seen by a glance at the meteorological observations made at White River station), while in summer it is very unusual for the temperature to rise much above 80° (Fahrenheit), and in general it is much lower. The nights are always cool and are often so cold that summer frosts occur. These, however, are rarely heavy. The winter may be said to last from the beginning of November to the middle of April, but there is little growth till the end of May. In general the climate is more severe than in the country north of the Height of Land almost as far as James Bay, the winters equally long and quite as cold, and the summers on the whole shorter, rainier, and not nearly so warm. The difference may in general be said to be due to the proximity of the Michipicoten country to the icy waters of Lake Superior on the one hand, and to the protection afforded to the Hudson's Bay slope north of the Height of Land by the rocky hills which border Lake Superior on the other hand.

Game and Fish

Game is fairly common in the Michipicoten area. Since many of the Indians have given up hunting and have taken to living by means of whatever work they can get near the Lake Superior shore, game in general may be said to have rapidly increased. Caribou and red deer are espesially common in many parts of the country, and though few moose were seen by my party during the past summer, still, I understand from the Indians that this large and splendid animal is not rare in Michipicoten. Bears also are common, especially near the Lake Superior shore, where they find abundant agreeable food in the numerous berries which cover the rocky hills towards the close of summer.

Martin, mink and foxes are uncommon according to Indian report, but I was really surprised at the number of beaver in the region. In our frequent traverses across country we were constantly coming upon fresh dams built by these interesting animals, and in many places the flooded marshes and enlarged ponds caused by these dams were observed to have decidedly influenced the physiography. This winter I am afraid many of these beaver will go, as once the Indians know of their whereabouts, they cannot resist the temptation of partaking of so dainty a morsel as beaver meat. The killing of the beaver by the Indians is particularly dangerous, as it means practically the extermination of the animals in the particular part of the country where the Indians hunt, since it is their custom to wipe out an entire colony of beaver and leave none to breed.

Rabbits were very common in Michipicoten during the past summer, but muskrats were noticed to be especially rare.

Nearly all the larger inland lakes and even many of the small ones are well suppiled with fish, but not with trout, as most people imagine. Pickerel, pike, and suckers are the commonest fish. Brook trout are found in the Pucaswa river, in the Magpie river, and in many of the small brooks near Lake Superior. The mouths of these various streams are a common resort for the Indians during the early autumn when the larger lake trout ascend the streams. White fish are to my knowledge not found in any of the lakes west of the Magpie, though they are plentiful in Dog lake and other lakes west of that stream; and are of course the principal fish in Lake Superior. It is remarkable that Michi-Biju lake, Michi lake, and Katzenbach lake contain no fish, although they are all good-sized bodies of fine clear water. The absence of fish is said by the Indians to be due to the presence of certain sulphur springs, but I could find no visible evidence to support this hypothesis.

The Native Inhabitants

There are now very few Indians left in Michipicoten, and those who still remain have lost most of the fine qualities characteristic of the Ojibway Indian, to which

tribe they belong. Most of them spend their summers living in small wooden houses or in cotton tents at White River station or at the new Roman Catholic mission, which is situated on the Lake Superior shore about two miles west of Michipicoten Harbor. At one or other places they find the occasional brief employment, pleasing to an Indian, either in fishing at one or other of the fishing stations, or in acting as guides to tourists or exploring parties. They never seek steady employment, and for the most part take to the woods in October, where the winter is passed in hunting and trapping. Caribou and rabbits are during this season their chief provision. Few of the Indians now depend much on the furs they can trap, and the catch has been so small in recent years that the Hudson's Bay Company's post at Michipicoten river was closed last summer after having been open for the second time since 1898. In general the Ojibways of Michipicoten are fairly well-to-do, though unhealthy like all savages who have come into contact with the white man's civilization. The morale of those who

Indian camp, near Dog river.

live near Michipicoten Harbor is superior to those who live around White River, since a shocking traffic in whisky goes on with the Indians at the latter place. Nearly all of them now speak English, and in a general way it may be said that the uselessness of an Indian increases directly in proportion to his knowledge of English, or in fact any language other than his own. They have long dressed in European costume, which on them looks essentially grotesque and hideous. The birch bark canoe and the birch bark wigwam, once so common and always so picturesque, are now disappearing from Michipicoten, and the unfortunate Michipicoten Ojibway is year by year becoming more and more like the worst class of the white men with whom he now has free intercourse.

The scenery of the district is generally lovely. The numerous lakes of multiform fantastic shapes, indented by deep bays in all directions and dotted by rocky tree-girt islands, the rugged hills seared by the atmosphere of ages, the dark spruce forest extending to every quarter, and the short stretches of lily-filled calm on the rivers

broken by longer sweeps of foaming rapids or falls, or by high-walled canyons—these are all beautiful and give an ever-changing, shifting scene, but always of the same general character. The numerous lakes and the rivers are a continual source of joy to the voyageur throughout Michipicoten. They make travelling by canoe, and camping in the wilderness a delight. The rough rugged coast of Lake Superior, indented by narrow fiord-like bays or varied by cliffs rising abruptly from the water's edge or by long stretches of sand beach, lends a continual charm to the scenery of the north shore.

Water Power Sites

There are a great many sites of hydraulic power on the various streams in the area under discussion. Perhaps the ones most suitable for early development, owing to their proximity to the shore of Lake Superior, are the falls near the mouth of the Pucaswa river, Denison falls near the mouth of Dog river, and the two series of falls near the mouth of the Magpie river.

During the past summer the writer and his party were the recipients of many kindnesses, and we were courteously aided in our work by the various people throughout this district, but acknowledgments are especially due to Prof. A. B. Willmott, Superintendent of Mines for the Lake Superior Power Company, to Mr. R. W. Seelye, Manager of the Helen Mine, and to Mr. W. H. McDougall of White River.

GENERAL STRATIGRAPHY

The rocks of the Michipicoten Iron Range, like those of all the iron ranges of lake Superior, are geologically of great antiquity. Though presenting some slight points of difference, they closely resemble the rocks of the Vermilion Iron Range, and are probably of practically the same age; but it is somewhat hazardous to correlate rocks of districts so widely separated.

The stratigraphical succession of the region in ascending order may be given as follows:[12]

Lower Huronian	1. Michipicoten schists, etc. 2. Helen iron formation.
Unconformity.	
Upper Huronian	Doré formation.
Post-Huronian	Acid eruptives.
Keweenawan	Basic eruptives.

The Lower Huronian rocks of Michipicoten are doubtless the stratigraphical equivalents of the Archean rocks of the Vermilion iron range, and the Upper Huronian of Michipicoten, the analogue of the same section. In the nomenclature of these series I have followed the usage of previous geologists in the region. The Post-Huronian acid eruptives are usually called Laurentian. The basic eruptives are probably of the same age as the widespread occurrences of similar rocks within the Nipigon or Keweenawan series. All of these points will be considered later in greater detail.

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[12] NOTE.—Since this paper was written the Report of the International Committee on the classification of the pre-Cambrian of the Lake Superior region has been published (Journal of Geology, Vol. XIII, No. 2, 1905), and is reproduced elsewhere in this volume. What is here called the Lower Huronian is apparently equivalent to the Keewatin in the Committee's scheme of classification. On the Vermilion Iron Range of Minnesota, for example, the Keewatin is said by the Committee to consist of (1) the Ely greenstone and (2) the Soudan iron formation, which correspond apparently to Dr. Bell's Michipicoten schists and Helen iron formation respectively. The Upper Huronian or Doré formation probably corresponds to the Committee's Lower Huronian. Dr. Bell does not use the term "Laurentian" which the International Committee retain at the base of their scale in eruptive contact with the Keewatin, but apparently the Post-Huronian acid eruptives of Dr. Bell's paper may, at least in part, be included in the Laurentian as defined by the Committee. T. W. G.

Geologic History

In Lower Huronian times were deposited great thicknesses of igneous rocks. These are at times true lava flows, again intrusive sheets, and at other times tufaceous beds or volcanic clastics. Associated with these are true waterlaid sediments. By the close of Lower Huronian times folding of the strata had already commenced and shallow synclines were formed, in which were deposited the coarse conglomerates of the Doré formation; the larger pebbles and the finer material resulting from the erosion of the high land formed by the arching of the strata between the synclines During this time volcanic activity continued, allowing the deposition of further ash-like material within the Doré formation. Subsequent to Upper Huronian times were great intrusions of both acidic and basic rocks, the former taking place when the intense folding of this strata was well advanced, and the latter occurring when the folding had almost or entirely ceased.

The plication of the strata has been most complex, resulting often in closely compressed longitudinal troughs and arches, with more open transverse folds. The former are parellel to the trend of the iron ranges, the latter at right angles to it. The transverse folding has given to the longitudinal folds a more or less sharp pitch which, with the numerous secondary structures developed—cleavage, jointing and schistosity, produce a geologic condition most difficult to study. In a general way the northern Michipicoten Huronian area may be described as a synclinorium with a general eastward pitch and bounded on the south and north by resistant granitic rocks The western Michipicoten Huronian area is in part much less closely corrugated than the northern area, and its structure, which will be discussed later in connection with the special areas, is somewhat different.

As may be well imagined in a region of such complex structure, erosion has produced great irregularity in the distribution of the various formations, sometimes patches of one kind of rock being separated for miles from rocks of similar lithological characteristics.

THE MICHIPICOTEN SCHISTS

Dr. Coleman and Professor Willmott have divided the Lower Huronian of Eastern Michipicoten into four formations, named in ascending order as follows; Gros Cap greenstone, Wawa tuffs, Helen iron formation, and Eleanor slates. These stratigraphical subdivsions are not quite suitable for the northern and western Huronian areas, and some difficulty has been experienced in separating the members of the series and in assigning absolute positions to the divisions made. The decided band of ferruginous sediments which make up the Helen formation may be considered as occupying a definite horizon. In the northern Michipicoten area this formation generally lies close below the Doré formation, but in some parts of the belt masses of schists intervene between the Helen formation and the Doré formation. In the western Huronian area no such close relation between the iron formation and the conglomerate is observable. This varying position of the Helen formation with reference to the Upper Huronian indicates either an unequal denudation of the Lower Huronian previous to the deposition of the conglomerate, or otherwise an unequal deposition of volcanic material after the Helen iron-bearing rocks had been laid down. Again, tremendous folding and faulting, followed by an enormous and, in different parts of the area, very unequal removel of material, have doubtless seemed to alter the original relations existing between the Upper Huronian and the Helen formation giving rise to frequent misinterpretations of the true condition. In some places especially in the northern belt, the width of the Helen formation appears to diminish and at the same time there is a relative increase in the amount of schist overlying it,

which seems to suggest that in these parts of the area towards the close of Lower Huronian times chemical sedimentation was relatively overpowered by volcanic deposition, whereas elsewhere the former still continued.

The lithological equivalents of the Eleanor slates are comparatively rare in the northern and western parts of Michipicoten, and referred to the Helen formation they occupy no definite position, being either below the iron-bearing rocks, above them, or even intercalated with them. In general, however, (though sometimes in no close relation whatever with the iron formation), they are intimately connected with the Helen formation, and are merely an argillaceous phase of it. Still further, the schistose greenstones, common in northern, though rare in western Michipicoten, which may be considered as analogous to the Gros Cap greenstone, do not always occupy the lowest part of the series and are frequently interstratified with the various igneous schists, which in southern Michipicoten make up the Wawa tuff formation.

Owing to this uncertain relative position of the different members of the series, it has been considered best for the present report to neglect the previous terminology and to make only two divisions in the Lower Huronian—a definite division, the Helen formation, to embrace all iron-bearing cherts or their metamorphic equivalents, together with any other sedimentary rocks, either chemically or water deposited, which may be intimately associated with them—and a somewhat undefined division, the Michipicoten schists, to include all igneous rocks whether extrusive or intrusive, together with any sedimentary rocks, however formed, not immediately associated with the iron-bearing rocks of the Helen formation. These sedimentary rocks not associated with the Helen formation would naturally be connected into a separate formation, were it not that the outcrops of the clastics are very few and bear no relation whatever either structurally or chemically to each other. The new classification is to some extent independent of any age considerations, though the schists are generally older than the rocks of the Helen formation, and compose by far the largest part of the Lower Huronian.

The Michipicoten schists consist of a great complex, comprised in the main of definitely igneous rocks varying in chemical composition from decided basicity on the one hand to pronounced acidity on the other, with which are associated rocks of doubtful igneous origin and a very few rocks of sedimentary origin. All of these rocks, whether sedimentary or igneous, are more or less schistose and often receive the name of ''green schists'' from their very general green color. The definitely igneous schists comprise the following varieties: schistose greenstone, chloritic and micaceous schists, schistose quartz-porphry, quartz porphyry schists, felsite schists, schistose porphyries, carbonate, schists, and finally amphibolites. The questionable schists are either carbonate schists, chloritic schists, or amphibolites. The distinctly sedimentary schists are either schistose arkoses or phyllites.

The Schistose Greenstone

The schistose greenstone is a predominately massive rock, strikingly simulating in the field an altered diorite or gabbro. Its origin is prabably chiefly from these plutonic rocks, though it is possibly derived in a very small part from true lava flows especially when it exhibits the ellipsoidly-parted structure analogous to that described by Clements as occurring in the Ely greenstone of the Vermilion district. In northern Michipicoten this last texture is very rare, and as a rule the greenstone is a soft rock of medium to coarse grain, generally with a more or less imperfect schistose structure. In texture it is frequently poikilitic but rarely porphyritic.

The principal alteration of the rock has been metasomatic, comprising chiefly the phenomena of sericitation, chloritization, and carbonatization. Two or all of these processes acting together often give the rock a mottled green appearance. In weathering the rock freqently become covered with a pinkish or grayish white crust, which

very often gives it the appearance from a distance of a granite or felsite. Often associated with the schistose greenstone and occasionally grading imperceptibly into it, is a fine-grained, soft, chloritic, highly schistose rock, which is apparently sometimes intruded by the schistose greenstone, but much more often intercalated with it. These much sheared rocks have been tentatively regarded as tufaceous deposits. Their history will be enlarged upon further on.

Petrography of the Schistose Greenstone

Little can be gained by the microscopic study of the schistose greenstone. The original minerals still remaining are plagioclase, hornblende, augite, magnetite, ilmenite and apatite. Both the hornblende and plagioclase are greatly altered; the plagioclase so much so that no more definite mineralogical composition can be assigned to it. With these primary minerals are associated the following secondary constituents —chlorite, quartz, chalcedony, pyrite, zoisite, sericite, epidote, titanite (leucoxene) and carbonate. Chlorite in large irregular areas eating into both the feldspars and hornblende, is the predominating mineral, though epidote in large radiating sheaves, and zoisite in tabular aggregates have frequently replaced the hornblende and invaded the plagioclase areas as well. Sericite and a carbonate which is sometimes ferruginous, as judged from its frequent alteration to limonite, often replaces plagioclase, and quartz, as observed in one instance at least, forms an exact pseudomorph after that mineral. Quartz and carbonate often fill secondary cracks, and these infiltrations are not infrequently rusty from the alteration of the cárbonate.

Distribution of the Greenstone

The distribution of the greenstone is extensive throughout the northern Michipicoten area. The shores of Sigami lake, north of Iron lake, are entirely composed of this rock, and it forms the prominent part of the low hills stretching westward from that body of water beyond Nichols lake and eastward to the north of Pitch Pine lake, to the Dog river. Again it appears prominently south of the Frances mine towards Lac à la Plonge, outcrops at frequent intervals along the southern part of Paint lake and of Sage lake, and southward from Kabenung lake, towards the contact with the Post-Huronian acid eruptives.

By intense dynamic strain the schistose greenstones are sometimes metamorphosed to talcose and chloritic schists, though these rocks are formed more frequently from the finer-grained schists associated with the greenstone, which were probably originally tuffs or lava flows, or may even have been water-formed argillites. Definite proof of the extrusive igneous origin of some of these rocks is found in the frequent occurrence of amygdaloids. With these amygdaloids are sometimes associated rocks which contain no amygdules, but resemble closely the groundmass of the true amygdaloid or are even more highly sheared. These very schistose rocks sometimes occur quite independent of, and at long distances from the nearest amygdaloid, but from their lithological resemblance to the latter, and because of the occasional presence within them of small rounded fragments which resemble lapilli, they have generally been regarded as altered tuffs, though they may in part be very much altered phyllites. The amygdaloidal structure is remarkably well shown on the weathered surface of the true amygdaloid, and the frequent occurrence of amygdules in a soft groundmass so strikingly simulates the macroscopical appearance of the Doré conglomerate that in several instances in the field the lava was with difficulty distinguished from the conglomerate.

Originally the groundmass of the amygdaloids was probably a basic glass or a fine-grained mass consisting chiefly of plagioclase and some ferromagnesian mineral. The latter has now entirely disappeared, but under the microscope the former is frequently recognizable and is seen to interlock in ophitic structure with the plates of chlorite developed from the antecedent ferromagnesian mineral which was very probably augite.

The laths of altered plagioclase are often entirely replaced by secondary chlorite, chalcedony and carbonate, the latter more or less decomposd with the formation of hydrous iron oxide.

The amygdules contain chlorite, carbonate and quartz, sometimes consisting of one of these minerals, sometimes of two, and often of all three—thus exhibiting amygdules of different colors, although predominately whitish or yellowish or reddish due to the oxidation of the carbonate. When the three minerals are present, ordinarily the outer rim, along the edge of the amygdule, consists chiefly of chlorite with a little carbonate, then one of quartz, at first coarse-grained but becoming saccharoidal towards the centre, and finally often a central core of carbonate. At other times apparently the paragenesis is reversed, and all the carbonate forms subsequent to the quartz.

The amygdaloidal chloritic schists outcrop immediately north of the range at Iron lake, and in some places south of it towards Windigo mountain, again north of Sigami lake and near the shore of the marsh on the portage between the Frances mine and the Dog river. The lateral extent of the true amygdaloids is small, and the rock often grades imperceptibly into schists which show no amygdaloidal structure. The latter—the common chlorite schists—have a widespread distribution intercalated with the various other schists throughout the region.

The schistose quartz porphyry and the quartz porphyry schist are chemically of practically the same composition, but they are apparently of slightly different mode of origin, the latter being effusive and the former intrusive, though probably at no great distance beneath the surface existing at the time of intrusion. This relation between the two rocks is judged from the small embayments of schistose quartz porphyry extending into the quartz porphyry schists. It is possible, however, that the schistose quartz porphyry may be merely a less mashed phase of the quartz porphyry schists, though the great linear extent of these rocks seems to preclude this hypothesis.

The quartz porphyry schist is often intensely sheared, splitting into thin bands a fraction of an inch in thickness. The schistose quartz porphyry on the other hand is remarkably massive, and is frequently shown topographically as the summit of a low ridge standing above the more friable quartz pophyry schists, with which it is apparently always connected. As it is occasionally granitoid in texture, it is sometimes with difficulty distinguished from the fine-grained porphyritic granites of the same age as the immense granite intrusions which succeeded the deposition of the Upper Huronian rocks.

Microscopically the quartz porphyry schist is a nearly gray greenish or pinkish rock containing numerous blebs of clear glassy quartz. The schist sometimes shows slight variations in color and texture, indicating successive flows resembling bedding planes. These planes are usually in accordance with its highly developed schistosity Beneath the microscope its decomposed groundmass is seen to be composed chiefly of the following minerals: orthoclase, plagioclase, sericite, quartz and chlorite. In the more altered varieties the orthoclase and plagioclase are entirely changed to sericite, but in others the alteration has not proceeded so far. The plagioclase is a somewhat acid oligoclase, but occasionally it is basic as andesine. In the metasomatic replacement of the feldspars, chalcedony and carbonate have always developed in connection with sericite. Where not decomposed, the groundmass shows a distinct felsitic texture. There is a marked tendency for the alteration products to arrange themselves in parallel lines along the planes of foliation. The phenocrysts are of three kinds: quartz, plagioclase and orthoclase. Rocks in which quartz is the chief phenocryst are the most common. The phenocrysts are for the most part relatively large and those which are of feldspar have not undergone as great alteration as the groundmass. The quartz is usually rounded, but sometimes shows the faint outline of the double pyramid. Orthoclase appears in large Carlsbad twins, and plagioclase, which ranges in acidity from acid oligoclase to andesine, shows twinning both after the albite and pericline laws. Both quartzes and feldspars have been granulated, and the

latter are often surrounded by a halo of secondary minerals—quartz, sericite, carbonate and hydrous iron oxide. Occasional large plates of chlorite may represent original phenocrysts of biotite bleached of their iron constituent.

The schistose felsites and the felsitic schists are the less silicious equivalents of the schistose quartz porphyries and the quartz porphyry schists, into which the former imperceptibly grade by the addition of more quartz in the groundmass and the development of phenocrysts of the same mineral. Owing to the extensive sericitation which both the quartz porphyry schists and the felsite schists have undergone, they might be more correctly classed together as sericite schists. Chemical changes have considerably altered the quartz-porphyry and felsite schists, resulting at many points in their being greatly silicified. Again, secondary carbonates have been extensively formed. From the oxidation of these rocks result the rusty silicified schists common in many parts of the district. It is possible that much of this carbonate and silica was original and was deposited between flows as small lenses of chemical sediment interstratified with the more extensive igneous material. The sericite schist of both the quartz-porphyry and the felsite facies are among the commonest rocks of the Lower Huronian in northern Michipicoten, and are frequently found immediately underlying the Helen formation and occasionally overlying it. They are not so commonly distributed in western Michipicoten, but occur prominently just west of Fall creek and elsewhere. When they have undergone silicification and carbonatization, they are sometimes almost indistinguishable from some of the cherty carbonates of the Helen formation.

Other Types of Schist

Closely resembling from a textural standpoint the quartz-porphyry schists and felsite schists, are the various porphyritic schists, which represent the effusive equivalents of plutonic rocks varying in acidity from basic syenites or acid diorites to gabbros. A syenite porphyrite schist is quite commonly connected with rocks of the Helen formation in western Michipicoten, especially north of Brown lake. The hand specimen shows a highly schistose dark gray rock, resembling a chlorite schist and specked with small pinkish blebs of feldspar. Beneath the microscope the large phenocrysts stand in marked contrast to the fine-grained groundmass. The phenocrysts consist chiefly of orthoclase and of plagioclase, which does not exceed the basicity of andesine. Both orthoclase and plagioclase are decomposed, much strained, and sometimes cracked and faulted. The groundmass, which is entirely altered, consists of a mass of chlorite, sericite, quartz, calcite, epidote, ziosite, and hydrous iron oxide.

The diorite-porphyrite schist which also occurs in the western Michipicoten Huronian, commonly contains phenocrysts of hornblende, of plagioclase, and a very few of biotite, the groundmass consisting of altered feldspars, quartz, chlorite, calcite and pyrite.

The various carbonate schists, calcareous, dolomitic, or sideritic, represent the extreme phase of the carbonization of the other green schists, more particularly the less massive phase of the schistose greenstone, which they closely resemble in physical appearance, and from which they differ chemically in the increase in the quantity of carbonate and, to a less extent, of silica.

The rock in the field is often hardly distinguishable from a much altered diorite or gabbro, but the more completely metamorphosed specimens are really impure limestones, dolomites, and siderites. For instance, at the extreme eastern end of Kabenung lake there is a rock of undoubted igneous origin, now almost completely composed of calcium carbonate, with small amounts of muscovite, zoisite, chalcedony and a very few much altered plagioclases, showing twinned striation. Again part of the coarse-grained schist on the Angel's Night Cap at Iron lake is composed principally of carbonate with light green chlorite, quartz, and some altered plagioclase. The quartz often forms exact pseudomorphs after plagioclase, while the carbonate replaces both

plagioclase and the original ferromagnesian mineral, of which chlorite is the bleached successor. Carbonate is also independently deposited in cracks. Chlorite is sometimes apparently a metasomatic product of plagioclase.

A sideritic schist ocurs on the portage from Pyrrhotite lake to Godon lake, which contains so much iron carbonate that by its oxidation it has given rise to small pockets of impure iron ore, of no economic importance. These deposits of siderite in many cases doubtless have resulted from the infiltration of material leached from overlying or adjoining rocks and deposited in the interstices of the schistose greenstones or other schists, but it is also due in part to the direct alteration of some of the original minerals, probably chiefly the ferromagnesian minerals—hornblende or augite.

The phenomena of chloritization, silicification, carbonatization and kaolinization, of hornblende or augite, may be theoretically expressed as follows:

$$5 \{ (Ca, Mg, Fe) O + (Al, Fe)_2 O_3 - 4SiO_2 \} 12 H_2O + 15 CO_2 = 5 CaCO_3 + 5 Fe_2O_3 + 5 FeCO_3 + 5MgCO_3 + 4 H_2O, 5 MgO, Al_2O_3, 3Si O_2 + 4(2H_2O, Al_2O_3, 2 SiO_2) + 9 SiO_2.$$

or the carbonization, silicification and kaolinization of plagioclase (acid labradorite).

$$2 (Ca, Al_2Si_2O_8 + NaAl Si_3O_8) + 3 CO_2 + 6 H_2O = 2 CaCO_3 + 3(2H_2O, Al_2 O_3, 2 SiO_2) + Na_2CO_3 + 4SiO_2$$

Metamorphosed Schists

Besides the peculiar forms already described, due to regional metamorphism, there are a number of other interesting rocks produced both by contact and dynamic metamorphism, more especially the former. Only a very few of these can be discussed in the limited compass of this report. They are apparently of three principal kinds—the epidote schist type, the hornblende schist type, and the biotite schist type. The epidote schist facies shows a rock in which the original mineral constituents, basic plagioclase, and amphibole or pyroxene have been metamorphosed to a mass of epidote, zoisite, quartz, chalcedony, chlorite and often magnetite, but showing sometimes fragments of original feldspars or ferromagnesian minerals. This rock is especially common along the contact of the schist with the large masses of Post-Huronian acid eruptives, especially where narrow sheets of the acid intrusive are intercalated with thin beds of schists. The phenomenon was seen to best advantage in the fire-swept stretch of country just north of lake Charlotte. The epidote schist type is apparently formed from the finer-grained chloritic schists.

Often appearing close to the contact of the post-Huronian eruptives, and even included as small areas within them are rocks of the hornblende schist type. They were also noticed in several places as the product of dynamic metamorphism, or what is apparently so. Beneath the microscope the rock appears entirely re-crystallized, and consists usually of hornblende, epidote, magnetite, quartz, and sometimes plagioclase (labradorite?) with calcite, biotite and chlorite. The light and dark minerals are associated in more or less parallel bands. This rock may be found on the shores of Brant lake, south of the Grand Portage, as narrow bands of included schists in granites, etc.; west of Richardson's Harbor towards Otter Head, in connection with the magnetite schists of McDougall's lake; and elsewhere. The hornblende schist type represents apparently the extreme phase of metamorphism of the chlorite schists. There are phases which are transitional between the chlorite schists proper and the purely hornblende schists. Sometimes the percentage of magnetite increases so much that they pass into magnetite schists. Narrow lenses of a magnetite hornblende chlorite schist (very rich in magnetite) occur on the north side of the Pucaswa river about two miles above its mouth, and these probably represent enriched narrow zones formed by differentiation by compression of some basic igneous rock like gabbro. They possibly resemble on a very small scale the immense lenses of magnetite in horn-

blende and chlorite schists at Sydvaranger in Norway, described by G. Henriksen.[13]

The biotite schist type is much less common than either of the other two, but is seen typically to form low overhanging cliffs, rising ten to twenty feet above the waters of lake Kapimchigama, in the long northern bay, and I observed it at several other points. Megascopically in some ways this rock resembles the carbonate schists. It usually consists mainly of biotite, with lesser amounts of carbonate (calcite), magnetite, muscovite, talc, chlorite, residuary green hornblende, and altered feldspar. Originally the rock was probably a schistose greenstone or allied rock, composed mainly of amphibole (very possibly a paramorph after pyroxene), a little basic plagioclase, and more or less magnetite. However, the biotite, with intergrowths of muscovite, calcite, and chlorite, has almost entirely replaced the original material, though magnetite occurs everywhere quite unaltered as inclusions in all the secondary minerals.

The highly banded gneisses which occur within the granites of Otter Head and elsewhere, often in large areas, are supposed to represent extremely metamorphosed quartz-porphyries or felsite schists, or their deep-seated equivalents. This point, however, will be discussed later in connection with the post-Huronian acid eruptives.

A peculiar black schist was found on the east branch of the Pucaswa river north of David's lakes, and on the portage between Pyrrhotite lake and lake Marian, in connection with the carbonate schist already mentioned. The hand specimen shows a heavy black schistose or even slaty rock. Beneath the microscope the minerals chiefly showing are pyrite, more or less altered and in great irregular clumps, and much less quartz and chlorite. Sometimes the pyrite is in large crystalline areas unbroken by chlorite or quartz, again it is in small specks more or less segregated within streaks of chlorite and quartz.

It has been mentioned that silification is a common metasomatic change in the alteration of the quartz-porphyry schists. It was observed that this change was especially common where the rocks were in eruptive contact with large masses of intruded granite, and occasionally difficulty was experienced in ascertaining which was the intrusive and which the intruded.

The various pseudo-conglomerates which occur so widely in northern Michipicoten are sometimes almost indistinguishable from a waterlaid rock. One of these, the chlorite amygdaloidal schists, has already been described, but several others may be mentioned. Near the shore of Syenite lake occurs an amphibolite, an altered schistose greenstone, throughout which at one particular point rounded fragments very much resembling pebbles, are common. They are, however, all exactly the same, consisting of a mass of epidote, zoisite, chlorite and magnetite, and probably represent the corroded remains of fragments of original schist, into which the irruptive rock was intruded. Another example is the autoclastic rock seen west of Eccles lake (on the east side of the Magpie), and east of Godon lake. Here interbanded, softer and harder layers of felsite and quartz porphyry were first brecciated and then the harder fragments rounded by shearing.

Real Sedimentary Rocks

It has been mentioned that the distinctly sedimentary rocks within the Michipicoten schists consist of schistose arkoses and of phyllites. Schistose arkose has been found to my knowledge in the northern and western Michipicoten areas at only one point, on a small island near the eastern end of Reed lake, as narrow bands in connection with phyllites. The arkose macroscopically is a grayish schistose rock, looking not unlike an altered felsite, with which it may probably be sometimes confused in the field. Microscopicallly it is seen to consist of a somewhat fine-grained matrix of small rounded quartzes, muscovite and chlorite in small flakes, and crystalline calcite, in which are embedded the various larger fragments of quartz and both orthoclase and plagioclase feldspars. The feldspars, which are much altered to sericite and other secondary products, are more common than quartz.

[13] "On the Iron Ore Deposits of Sydvaranger, Finamacken, Norway," by G. Henriksen.

Highly schistose chlorite schists, which are definitely known to be sedimentary phyllites within the Michipicoten schists and with no connection with the Helen formation, are very rare. The rocks of this type, however, which outcrop in Dog River harbor, are distinctly sedimentary and have apparently no connection with the Helen formation, the nearest outcrop of which is two miles to the west. Similar phyllites appear on the islands at the east of Reed lake. These phyllites of Dog River harbor and of Reed lake resemble phyllites occurring with the iron formation at Iron lake, and even more so those which border the Doré conglomerate on the south side on the Magpie river, south of McKinnon's bridge. It is impossible from mere lithological reasons to connect these phyllites, without any definite stratigraphical connection, with either the Helen or Doré formations, and they are merely considered with the arkose above described as being sedimentary lenses within the much more extensive igneous material, though they may more correctly be isolated outcrops belonging with the argillaceous rock of the Helen formation or Doré formation.

The outcrop on Dog river is interesting, and I shall describe it somewhat in detail. There are two bands of phyllite. The most eastern band strikes about N. 80° W., and has a very slight inclination from the vertical. It consists of black phyllite interbanded with light grayish phyllite, both more or less rusty, due to the oxidation of pyrite. The outcrop is twenty feet wide. A gravel beach borders the rock on the east side, but at seventy-five feet in that direction an almost massive greenstone schist appears. On the west side of the phyllite lie seventeen feet of light greenish schistose agglomerate, beneath which is a schistose greenstone for twenty-four feet, then seven feet of rusty chloritic schist (which may be sedimentary), and then the second band of phyllite five feet wide and closely resembling the first band in general appearance, but which strikes N. 40° W. and dips northeastward at 52°. Beneath the second phyllite band lie chloritic schists, which appear as if of igneous origin.

In the microscopic cross-section the sedimentary origin of the phyllite is ascertained by the presence of rounded quartzes and of frayed fragmental chlorites or micas. The light gray phyllites seem to owe their color to the presence of considerable sericite, whereas the dark coloring of the blackish phyllites is due to the presence of carbonaceous matter.

The band of phyllites which appears on Dog River harbor outcrops at several points along the portage trail from the harbor to the first lake on the route to lake Michi-Biju.

THE HELEN FORMATION

As already mentioned, the Helen iron formation (in northern Michipicoten at least) occupies a position generally close to the overlying Doré conglomerate, but sometimes great masses of green schist intervene between it and the Doré formation. The relations existing between these overlying green schists and the Helen formation will be seen when the special districts of Morse mountain and the Katossin claim are described later.

The Helen formation consists of a series of allied and related rocks named in order of their importance in the region as follows: banded chert, massive granular chert, sideritic chert, pyritous chert, banded jasper, rusty quartzite, grüneritic and other amphibolitic schists, cherty siderite, and iron ores—hematite, magnetite, pyrites and even pyrrohotite. Between these rocks there is every phase of gradation. Besides these ferruginous rocks the formation includes a number of argillaceous rocks, phyllites, and biotitic and epidotic schists—all undoubtedly sedimentary which are found not only interstratified with the ferruginous rocks but also both above and below them, although always in intimate connection with them. These argillaceous rocks, as already mentioned, cannot be connected with the phyllites at Dog River harbor and at Reed lake, because there is apparently no stratigraphical connection between the phyllites of the Helen formation and the others.

Intercalated with the Iron formation at Iron lake are carbonate schists which were at first supposed to be contemporaneous with the iron formation, but which are in reality sheets of basic igneous rocks, injected parallel to the bedding of the sediments, and apophyses from the wide dikes of post-Huronian basic eruptives which cut the formation, and since their injection much altered by metasomatic changes. They will be discussed in connection with the rocks of which they are a part—the post-Huronian basic eruptives, and are mentioned here, merely because of the deteriorating influence which they exercise on the economic value of the iron formation at certain points.

The Iron-bearing Cherts

The banded chert is composed in its typical form of alternating narrow layers of whitish opalescent chert and silicious hematite or magnetite. In the northern Michipicoten iron range this form is rarely seen, though very common in western Michipicoten. The opalescent chert is usually quartzitic or granulated, and the silicious hematites are impoverished purplish jaspers, with which there is always associated some pyrite, though most of it may replaced by pseudomorphs of limonite. Beneath the microscope the whitish chert bands appear as a homogenous, interlocking, fine grained mosaic of quartz, while the purplish layers consist of much stained quartzes thickly mixed with specks and small areas of hematite, hydrous iron oxide and more or less oxidized carbonate or pyrites.

The banded cherts are often brecciated, and the fragments re-cemented by secondary quartz. In this autoclastic rock the original ferruginous bands appear as angular reddish areas in a matrix of whitish quartz.

The sideritic chert consists essentially of two minerals—quartz and siderite, with which are almost always associated chlorite, sericite, pyrite, oxidation products of pyrite and carbonate, and sometimes microcline and other feldspars. Examined microscopically, some of the quartz is seen to be clastic, but most of it is chemically precipitated, often in the form of chalcedony. Both microcline and chlorite, the former in rounded grains and the latter in plates with frayed edges, are fragmental, and their areas have been greatly reduced by the invading carbonate. Pyrite is frequently an inclusion in both the chlorite and carbonate, and it occasionally develops in secondary veinlets in association with chlorite, carbonate and quartz. Some of the sideritic cherts contain so much chlorite that they pass into cherty sideritic phyllites, of so much microcline that they become sideritic arkoses.

The massive grayish, pinkish or whitish chert, when quite pure and undecomposed, is holocrystalline and beneath the microscope is seen to consist of an interlocking mosaic of quartz. This is the "sandstone chert" of the Michipicoten prospector. It is often markedly rusty, due to the oxidation of iron carbonate, and less frequently iron pyrites, both of which are nearly always present. With an increase of one or other of these minerals, the rock passes into a sideritic chert or pyritous chert.

Occasionally the chert is almost black in color, amorphous, and with its constituent minerals entirely unseparated into bands. This phase, when viewed microscopically, is seen to be composed of a fine mosaic of quartz, often chalcedonic, with a great deal of chlorite in small flakes, and with considerable magnetite or pyrite, or both, as tiny inclusions in the chert or as automorphic grains or aggregates. By arrangement in bands and decrease in the quantity of pyrite this grades into the normal banded chert.

Allied to the granular chert and often almost indistinguishable from it in the field, is a coarse-grained rusty quartzite. This rock beneath the microscope shows tremendous shearing The quartz individuals are drawn out in long ribbons, with a general parallel alignment of the main axes of the grains, but with sweeping curved boundaries. The "ribbons" are surrounded by a mosaic of granulated quartz and are crossed by tiny sutures filled with similar material. The whole has been re-cemented by secondary quartz.

True banded jasper or "jaspylyte," is comparatively rare in the Michipicoten district. It occurs north of Iron lake, on the Katossin claim, on the shore of lake Superior three and a half miles west of the mouth of the Pucaswa, and east of the Magpie, and is hence worthy of mention. It consists of interbanded layers of crimson jasper with either bluish specular hematite or magnetite, or both mixed.

Metamorphosed Ferruginous Cherts

Sometimes the ferruginous cherts are so intensely altered by either contact or dynamic metamorphism that various amphibolitic schists result. These are of three kinds—the grünerite facies, the actinolite facies, and the hornblende facies, depending on the character of the original rock from which the metamorphic rock was derived. Every phase of alteration can be traced from a cherty rock in which the small and few blades of grünerite, actinolite, or hornblende are only distinguishable under the microscope, to those which resemble an amphibole schist formed by the alteration of an igneous rock. The alterations are due almost always to contact metamorphism, although instances resulting from what is apparently dynamic metamorphism are not unknown.

The grünerite type shows remarkably even separation into bands, light grayish green and black in color. The light colored bands are composed of a radiating interlocking belt of long lath-shaped grünerite crystals, containing a very little magnetite and a few residuary quartzes—the remnants left by the invasion of the grains of grünerite. The dark bands consist chiefly of magnetite, with lesser amounts of grünerite and quartz. The magnetite is gaining at the expense of quartz.

The actinolite schist type exhibits macroscopically a light grayish-green rock, often stained with iron rust, generally very highly foliated, and sometimes soft and friable. The thin section shows a mat of fine actinolite needles, almost entirely replacing a quartz mosaic, which is but faintly visible, and holding in their interstices, and sometimes as inclusions, automorphic grains and small aggregates of magnetite. Grünerite at times probably replaces actinolite and the rock then grades into a grünerite schist.

The hornblende schist derived from the metamorphism of a ferruginous sediment resembles remarkably that derived from the metamorphism of a schistose greenstone or chloritic schist, though as a rule the banding is more uniform and the percentage of quartz greater in the sedimentary rock. Beneath the microscope the hornblende schist is seen to contain the following minerals, quartz, with chalcedonic silica, hornblende, epidote, biotite, chlorite, carbonate, magnetite, and rarely apatite, arranged in parallel bands of dark grayish green and black. The grayish green bands consist chiefly of quartz, chalcedony and hornblende the latter gaining at the expense of quartz. Chalcedony, when present, advances almost as steadily as hornblende. Epidote and hornblende with magnetite make up the darker bands. The epidote and hornblende are intergrown in apparently contemporaneous growth, appearing in long attenuated sheaves, with their long axes parallel to the planes of schistosity. The magnetite is contained as inclusions within both epidote and hornblende, and as independent crystals and aggregates between their interstices. No quartz save that which is found as inclusions in the ferromagnesian minerals, is found in the darker bands. A little residuary carbonate and chlorite, still left unaltered from the original rock, are generally present, and these may be in very considerable quantity. Biotite and apatite are comparatively uncommon inclusions. Sometimes there is no magnetite in the rock, but a great deal of both epidote and hornblende and some apatite. In this case the rock has evidently resulted from the alteration of a cherty carbonate rich in lime and magnesia and poor in iron oxides; and probably containing much chlorite.

As may be judged from the products of alteration of the cherty iron carbonate, few of them are pure cherty siderites. Analyses were made of several specimens. One sample from McDougall's promontory on Iron lake gave the following result:

	Per cent.
$FeCo_3$	37.01
$MgCO_3$	7.95
SiO_2	52.36
H_2O, etc	2.+

while other analyses showed lime.

Petrography of the Phyllites

The argillaceous rocks associated with the ferruginous rocks of the Helen formation are phyllites, and rocks derived by metamorphism from phyllites. The rocks of this character, which have been definitely ascertained to be of clastic origin are rare in Michipicoten, though there are a great many doubtful rocks which are now tentatively classed with the Michipicoten schists, and which may really belong with the phyllites. The few occurrences of definitely ascertained phyllites are so widely separated that it would be impossible to classify them as one bed.

Generally the only methods of determining the origin of the phyllites are by their very even banding, by their often pronounced slaty cleavage, and by their direct association with iron-bearing rocks undoubtedly sedimentary, but occasionally the origin is also discoverable microscopically by the presence of decided rounded grains of clastic quartz, or by frayed fragmental biotites or chlorites.

The phyllites are both light-colored and dark-colored. The light- colored phyllite, a very cleavable rock, consists essentially of chlorite and sericite with generally a little quartz. A light-colored tourmaline is occasionally abundant, and there is always probably a little carbonate.

The dark-colored phyllites owe their color to the presence of a large amount of what is apparently carbonaceous material. They are very evenly and often crenately banded in very thin layers of lighter and darker material. The darker material consists of chlorite, biotite, hematite, carbonaceous matter, and a little chalcedonic silica. The biotite and chlorite are arranged with their long axes parallel to the foliation of the rock. The whitish bands are composed of chalcedony, some clastic quartz, light greenish chlorite, and a little hematite. The clastic quartzes are drawn into long narrow lenses wedged in between foils of biotite and chlorite.

By their further metamorphism, owing to the intrusion of igneous rocks, the phyllites alter to epidotic and micaceous schists. The epidotic schists are megascopically rusty weathering fine-grained rocks, often showing banding but very slightly cleavable. Beneath the microscope the banded varieties show layers of epidote, chlorite, zoisite, quartz, chalcedony, and a little hematite and magnetite, intercalated with layers consisting chiefly of magnetite with a little chlorite and chalcedony. The minerals are nearly all secondary, and only some of the chlorite and a few of the larger quartzes, which are drawn out in lensoid shape parallel to the schistosity, are clastic and original. Sometimes the epidote is entirely replaced by zoisite, with which are associated garnet, muscovite, pyrite and chalcedony, and there is sometimes a little original or secondary carbonate.

The micaceous schists show the development of biotite and muscovite in bands, separated by layers composed chiefly of quartz, often chalcedonic.

The degree of alteration of the phyllites varies with their position with reference to the dike or boss which caused their metamorphism, the change being greatest immediately adjoining the eruptive rock, and gradually diminishing away from the contact to the sediment changed only by the general regional metamorphism.

Structure of the Helen Formation

As most of the rocks of the Helen iron formation are of a hard resistant nature, they become fractured, brecciated and jointed rather than cleaved, though the phyllites and their metamorphic products, as well as the altered rocks resulting from the ferruginous sediments, often are decidedly schistose. Pronounced faults in the iron formation may be seen in several parts of the north and west Michipicoten ranges.

Among these may be mentioned one on the property formerly owned by the Minnesota Iron Company, west of Iron lake, two on the prolongation of the Leach lake bands north of the Grand Portage, and one on the portage from Floating Heart river to Cameron lake; doubtless also there are besides these larger and more apparent faults, innumerable instances of minor faulting or shifts of accommodation which are not so easily seen.

Genesis of the Helen Iron-bearing Rocks

The Helen formation is chiefly a chemical sediment, but it is also in part mechanical, as seen by the beds of cherty quartzites, cherty arkoses, and other decidedly clastic rocks which are associated with it.

It has been mentioned that igneous schists rich in iron-bearing silicates (augite, hornblende, etc.) are common in the Lower Huronian. From these igneous schists may have been derived the ferruginous, magnesic and calcic material of the ferruginous sediments. The ferruginous material, leached from the igneous rocks was probably dissolved in the sea water either as carbonate or as sulphate. Owing to the probable excess of carbon dioxide over any other acid present in the dissolving water, it would seem reasonable to suppose that ferrous carbonate was the principal salt in solution. If the water were not shallow, and the ferrous carbonate in solution were not close to the surface of the water, it might sink and be deposited simply owing to excess in solution. Similarly the ferrous sulphate might also be deposited. Contemporaneously with the deposition of the ferrous carbonate, calcium and magnesium carbonates would be formed and deposited in greater or less amount. At the same time that these reactions were proceeding, chert was being formed from a sea water rich in silica (due to the disintegration of the silicates), and more or less mechanical material derived from the decay of the surroundng rocks was laid down with the more extensive chemical deposit. Within the oxidizing influence of the atmosphere near the surface, some of the carbonate may have been oxidized, and unless again carbonatized by the abundant carbon dioxide probably present in the water lower down, would sink to the bottom as hydrous ferric oxide. The ferrous sulphate in contact with the oxidizing influence of the atmosphere would similarly be oxidized to basic ferric sulphate. The phyllites of the Helen formation contain a great deal of carbonaceous material. If the ferric oxide and ferric sulphate were deposited within the influence of this material, then probably the ferric oxide would be reduced to ferrous oxide and unite with the carbon dioxide simultaneously formed, and ferrous carbonate would result, while the sulphate would be reduced to sulphide by the organic material. This may account for the abundant iron pyrites deposited with the various cherts of the iron formation.

Professor Van Hise considers that the carbonate and sulphate, transported to the water, were oxidized and sank to the bottom in this condition as ferric oxide and basic ferric sulphate. They there came in contact with carbonaceous matter, and carbonates and sulphides resulted, as above outlined. This may be the correct hypothesis, but it seems remarkable that extensive oxidation should have proceeded in water sufficiently rich in carbon dioxide to dissolve the carbonates, especially at depths away from sub-aerial influence, where the water may also have been saturated with ferrous carbonate. Furthermore, it seems hardly reasonable to imagine that oxidation of the carbonate in the solution, and the alteration of the oxide back to carbonate, could take place close together.

The preponderance of ferrous carbonate over calcic and magnesic carbonate in the cherty carbonates of the Helen formation may be explained by the importance action exerted by these salts on ferrous sulphate. This action depends on the greater affinity which magnesia and lime possess for sulphuric acid than for carbonic acid, and on the instability of ferrous sulphate. These reactions may be thus expressed:

$$FeSO_4+CaCO_3=CaSO_4+FeCO_3$$
$$FeSO_4+MgCO_3=MgSO_4+FeCO_3$$

Calcic carbonate has a stronger affinity for sulphuric acid than magnesic carbon-

ate, and in this way may be found an explanation for the excess of magnesic carbonate over calcic carbonate in the carbonates of the Helen formation; and it is possible that the following reaction may have occurred:

$$MgSO_4 + CaCO_3 = MgCO_3 + CaSO_4$$

The explanation of the non-appearance of $CaSO_4$ (gypsum or anhydrite) is the much greater solubility of this salt than any of the carbonates.

It has been mentioned that the iron-bearing rocks of the Helen formation are in part of mechanical origin. The definitely clastic material consists of the three minerals, quartz, chlorite, and microcline, and there are probably other minerals represented. The grains of the several minerals are all small and, as no pebbles exist, it is presumed that there is no pronounced unconformity between the Helen formation and the rocks beneath it; but there must have been at least a slight break to permit the corrasion of the pre-existing rocks. Quartz is a common mineral in the quartz-porphyry schists of the Lower Huronian, and from these may have been derived the supply of that mineral in the Helen formation. Similarly, hornblende, augite and biotite occur in the earlier rocks. From these the chlorite may be a product of decomposition. The occurrence of microcline is not so easily explained. Microcline, so far as known, is not now recognizable in either the felsitic schists of the quartz-porphyry schists — the only acid rocks of the Helen formation in which it might be expected to occur. It is quite possible that all the microcline may have disappeared in the sericitization of these schists, though this seems rather a contradictory suggestion to make of compact igneous material when it has withstood alteration fairly well as clastic material probably as fully exposed to surface and deep-seated metamorphism. Microcline is common in the post-Huronian acid eruptives, but they are of course later than the Helen formation. However, the occurrence of abundant microcline may indicate the presence of acid rocks in or below the Lower Huronian other than the quartz porphyry and felsite schists. The post-Huronian acid eruptives may be the re-fused equivalents of these earlier acid rocks.

Pure quartzites, that is, rocks consisting chiefly of quartz fragments, are very rare in Michipicoten, and with the clastic material there is always more or less material of chemical precipitation, and we have cherty quartzites, sideritic quartzites, etc. Similarly rocks consisting chiefly of microcline or other feldspars are never found in definite connection with the Helen formation, and though those which contain a great deal of microcline are spoken of as sideritic or cherty arkoses, it would perhaps be more correct to call them felspathic siderites or cherts. As already mentioned in connection with the sedimentary rocks of the Michipicoten schists, true arkoses are found on Reed lake, but there is no reason to suppose that these are of the Helen formation.

Most of the chert formed would be deposited free, forming sometimes beds of pure chert; again when mixed with carbonate, cherty carbonate; and when with pyrites, pyritous chert. From a subsequent alteration of these have resulted the other rocks of the iron range. It is possible that part of the banded chert is an original rock made up of ferric oxide, derived from the oxidation of ferrous carbonate at the surface interbanded with chert, and this suggestion seems to be supported by the record of borings at the Helen mine. These pass through alternate layers of cherty carbonate and of banded chert.

The mode of origin of the amphibolitic schists of the iron formation has already been briefly intimated. They are the result of either contact or dynamic metamorphism. The banded jaspers are supposed to be the product of deep-seated metamorphism, and in the Helen iron formation apparently occupy stratigraphically an inferior position. They result from the banded cherts by dehydration of the hydrous iron oxide. Originally formed at the surface as ordinary ferruginous chert, by sedimentation in bands, when deeply buried and folded the hydrous iron oxides were dehydrated and changed to hematite, which gave to the iron its specular character and altered the rusty ferruginous chert to crimson jasper. From still further changes

to the sideritic chert, banded cherts and jaspers, have resulted the deposits of hematite. This is too large a subject to be considered here, but briefly it is a process of direct oxidation of the carbonate and partly of enrichment due to the action of descending, and to a less extent, of ascending waters acting upon the iron sediments.

Deposits of pyrites and of pyrrhotite occur at several points within the area with which this report deals. As already mentioned, they are supposed to result from the reduction of the sulphate by carbonaceous material, which is found commonly in the phyllites of the iron formation. Apparently at these places the sulphate salt was more common than the carbonate salt in solution; or it is possible the segregation of the sulphide may be the result of enrichment due to metasomatic change subsequent to the deposition of the rock.

It was noticed that great quantities of the iron sediment were strongly magnetic, particularly the banded cherts, and even more so the banded jaspers and amphibolitic schists. It may be judged from this that the magnetite is a product of advanced metamorphism and is probably formed by the deoxidation of hematite or limonite in a deep-seated zone or along or near the contact of an igneous intrusion. The few small deposits of magnetite in Michipicoten have always been found where one or other of these phenomena has been operative. It is possible that magnetite may also be formed by the direct oxidation of ferrous carbonate, as at one point at least on the range just west of Iron lake, siderite and magnetite were found in intimate connection close to the edge of a diabase dike.

EXTENT OF THE HELEN FORMATION

Formerly the Helen Formation was of extensive distribution, and though at present much of it remains, still by far the greatest part has been removed by inter-Huronian erosion and to a much greater degree by the long continued post-Huronian erosion. It has been mentioned that the rocks of the western Michipicoten range are much less complexly folded than those of the northern range. For this reason, in part the removal by denudation of the formerly existing iron-bearing rocks has produced a different character of outcrop in the case of the western as opposed to the northern range. The western range now appears as several generally very narrow bands lying parallel and very close together in an iron-bearing belt in some places almost half a mile in width. Phyllites or schists of igneous origin separate the narrow bands of magnetic cherts and other ferruginous rocks from each other, within the iron-bearing belt. In the northern range, speaking somewhat roughly, the outcrops of the formation make up two more or less widely separated bands, running each in a general way east and west. These bands represent the opposite limbs of the complex synclinorium already mentioned in connection with the northern Michipicoten Huronian area. Between the two bands lie the thick beds of the Doré formation. In the west of the area only the northern limb appears prominently.

Northern Band of Northern Range

The northern band of the northern range extends brokenly from the eastern branch of the Pucaswa on the west to the McKinnon tote road near the Magpie river on the east. For some three miles west of Bole lake narrow outcrops of banded and very magnetic chert can be seen in the green schists, but these are not of economic importance, seldom if ever exceeding twelve yards in width. Eastward from Bole lake the really wide band commences, and from this point to the end of McDougall promontory at Red Pine point for a distance of about four miles there is a continuous outcrop of the Helen formation occurring in a series of high cliffs facing south. At Red Pine point the iron range disappears below the waters of Iron lake, and does not reappear until about one mile west of Clear Water pond, and rather more than

two hundred yards north of Iron creek. Here two parallel bands run about two hundred yards apart and are supposed to be the opposite limbs of a syncline of the second or third order, and both part of the northern band. These sub-bands are continuous for over half a mile, and on them is staked the Katossin claim hereafter described. Some three-quarters of a mile along the strike from the place where they die out, one or other reappears at a point about one-quarter of a mile north of Pitch Pine lake, and thence is continued eastward as an unbroken band almost to the Dog river. East of the Dog river is a narrow band of rusty pyritous chert less than a quarter of a mile long and of no economic importance. Farther east, north of the marsh, on the portages between the Dog river and the Frances mine, the formation once more shows up, appearing first as narrow lenses in nacreous much-sheared quartz-porphyry schist, and afterwards as several closely parallel bands. These are continuous almost to the shores of Paint lake, where the formation is cut by the high granitic boss forming mount Raymond. From this point for some distance the tracing out of the iron-bearing sediments is a matter of extreme difficulty, it being often almost impossible to distinguish between schists of igneous origin and those formed from the sediments due to the metamorphic action of neighboring granitic intrusives. Roughly, however, the wide band runs directly north from mount Raymond, bordered to east and west by granite or quartz-porphyry. About one-half a mile north of Paint lake the strike, if so complicated and brecciated a structure can be said to exhibit strike, changes to north 60° west, and the band assumes that direction. Beyond this point the few isolated outcrops of chert and schists, both profoundly altered, being cut by both acid and basic eruptives, were insufficient to explain the relations existing between the two rocks. The relatively high ridge of hills which extends northward from mount Raymond is broken by many wide deep valleys marking the erosion of former dikes.

Less than one mile and a half in a direction north 20° west from mount Raymond is Morse mountain. On the southern part of this hill chloritic schist alone appears, but the northern part of the hill shows a wide outcrop of banded and rusty chert which continue more or less in a direction north 30° east between Heart mountain and Cushing lake for a distance of about a quarter of a mile, where they disappear in low ground.

Some two hundred yards east of the north end of Heart lake is a narrow band of rusty chert about 650 yards long, running in a general direction north 30° east. To the south this is cut off by basic intrusives which near the contact have metamorphosed the sediments to amphibolitic schists. In this direction it was probably formerly joined to the Morse mountain band. To the north it is cut off by the narrow neck of granite and quartz porphyry which joins the main northern mass of post-Huronian acid eruptives with the smaller Kabenung lake boss. This band is interesting only from a scientific standpoint, as its widest part is only some fifteen yards across.

Opposite the confluence of the Crayfish river with the Dog river, in the thoroughly contorted schists cut in every direction by inclusives, both basic and acidic, occurs a narrow lens of a banded actinolite-magnetite schist which is apparently an altered sediment of the Helen formation. It is only a few yards long and dies out in "tails" in the schists. Some 450 yards west of Narrow lake the formation reappears and is traceable brokenly as far as the northern arm of lake Charlotte. The band is narrow, nowhere exceeding ten yards in width. Changes of strikes are frequent on this band, the vertically standing beds running at south 70° east at the western end of Narrow lake, at about north 70° east at the western end of lake Charlotte, and bending to the former direction farther east. North of this main band several smaller lenses occur in the highly metamorphic schists but they are quite unimportant.

Along the northern shore of East Kabenung lake narrow lenses of magnetic chert first appear in the schists towards the northwest end of the lake. These widen to form the band of Magnetic point, and of the adjoining islands to the east. A few lenses also occur on an island a quarter of a mile still farther east. From this point the next appearance is about twelve miles farther east and along the shore of Evans'

creek, and from two to two and a half miles northeast of Godon lake. Several generally parallel bands occur in this distance of one half mile across the strike, and extend for rather more than a mile in the opposite direction, dying out near the McKinnon tote road.

Southern Band of Northern Range

The southern band of the northern range from its extremely irregular distribution, particularly towards the western end of the area, seems to have suffered greater transverse folding than the northern band. It first[14] appears suddenly as a wide irregular mass of cherts, etc., at the Frances mine. About two miles southwest of the Frances mine a narrow lens of chert appears on the shore of a marshy pond, but this has apparently no connection with the main southern band. Eastward from the Frances mine a wide muskeg swamp stretches to the foot of Brotherton hill—the next outcrop of the Helen formation. From a careful study of the structure of both the Frances hill and of Brotherton hill, I feel confident that all of the iron formation which formerly existed between these two hills has been removed by erosion, and that the low swamp indicates the weathering of the softer green schists below the hard rocks of the iron range. East of Brotherton hill the Helen formation dies out for some miles, to reappear as several generally parallel bands to the east of No-fish bay of Kabenung lake. These bands have a general northeastern direction, and unite in an extraordinary hill at the northeastern end of No-fish bay and on the neck of the peninsula between No-Fish bay and Perry's bay. From this point the united band strikes first in a southeasterly direction, then in an easterly direction, and is continuous to the south of White Water Lily pond.

West of the entrance of Elmo creek into lake Elmo, narrow lenses of black chert are to be seen in the schists. East of the creek these unite to form a decided band of variable width, and of more or less regular strike, in a direction north 80° east, which is continuous for over a mile, then dying out in the tail-like lenses so common in Michipicoten.

East of Leach lake is a wide appearance of the Helen formation. Here three decided bands and many smaller sub-bands appear interstratified with the schists. I have designated these bands by the numbers 1, 2, 3, 4, 5, 6, counting from west to east, from where crossed by the township line—the northern boundary of township 30—and sub-bands A and B, the former a part of band 3, and the latter a part of band 2. Neither of these sub-bands crosses the township boundary line. Band 3 is the most prominent of all. Its branch, sub-band A, dies out just south of the forty and one-half mile post, but soon outcrops once more and is continuous more than half-way across the township, running with a regular strike almost east and west.

For five miles to the southeastward of the point of disappearance of sub-band A no outcrops of the Helen formation were observed. Then at a point less than a quarter of a mile from the eastern shore of Godon lake the iron-bearing rocks again outcrop prominently and run in a narrow broken band southward to the small pond lying east of Pyrrhotite lake and joined to it by a narrows; southeastward from this small pond the band is traceable as a narrow lens, appearing at wide intervals along the exposed western face of the ridge of hills, running to the east of Pyrrhotite lake, lake Marian, Punk lake and Emerald lake.

East of the Magpie are the Eccles lake claims, located in the southwest corner of township 28, and staked on a great many narrow lenses of Helen formation lying within their boundaries. These lenses of iron-bearing rocks may be said to mark the link between the northern and eastern Michipicoten iron ranges. They were somewhat hurriedly examined by the writer, and will be discussed in connection with this report. Though from a geographical standpoint, being east of the Magpie river, they

[14] A very narrow lens was found about three miles farther west, but it is of no economic value.

may be said to belong with the eastern iron range, still they are supposed to represent the continuation of the iron-bearing rocks on the opposite side of the Magpie, and hence are to be connected geologically with the northern range as well.

The Western Range

The western Michipicoten iron range, or the Pucaswa section, may be said to start on the Lake Superior shore about three and a half miles southeast of the mouth of the Pucaswa river. At this point some ten narrow bands of iron formation appear interstratified with schists. They are traceable for only a few yards back from the lake shore, and are lost beneath a sand-plain which extends northward almost to the banks of the Pucaswa river. Some three and a half miles slightly east of north of this first appearance of the western range is the second outcrop on Laird's claim. Here several narrow bands appear in the schists for rather over a quarter of a mile across the strike, and run for about the same distance along the strike. Less than half a mile farther east the bands reappear, not far north of the Julia river, and are brokenly continuous for a little over a mile. From this point where they die out to the western end of David's lakes is about three miles, and during this distance a few short lenses outcrop, but they are narrow and unimportant and extend for only a few yards above the generally level and little broken country.

David's lakes are situated some six miles north of Red Sucker harbor, and just north of the headwaters of Pipe river, although they themselves empty to the eastern branch of the Pucaswa, south of which they lie at a distance of rather less than a mile. Just north of David's lakes and extending about one and three-quarter miles to the northeastward is an iron-bearing horizon. The banded cherts which compose this horizon, are cut off to the eastward by the intrusive granite and disappear to the westward in low ground. On the bands of iron formation north of David's lakes are staked the David Katossin claims.

About four miles southeast of the point where the banded cherts of the David Katossin claims are cut off by the granite, they re-appear on the eastern limit of the eruptive rock to the northwest of Maple lake. From this point several narrow and parallel bands run north of Maple lake, and extend in a somewhat broken manner to and north of Lost lake to the Floating Heart creek. The band crosses Floating Heart creek and continues eastward to Cameron lake. On the eastern side of Cameron lake only a few scattered and very narrow lenses are visible. From Maple lake to Lost lake the western range is much drift-covered, and solid rocks, particularly those of the Helen formation, do not outcrop prominently, so that it is practically impossible to study the rocks of this section in any detail.

For some seven miles in a direction somewhat south of east of Cameron lake, granitic rocks occupy much of the surface of the country, and intervene between two patches of Huronian. Not far from the eastern margin of the granite, rocks of the Helen formation appear near the headwaters of Fall creek and at about two miles from the Lake Superior shore. They occur in disconnected scattered lenses which may be traced southward to the Lake Superior shore, where they outcrop a short distance west of the mouth of Fall creek.

About a mile and a half north of the mouth of the Pucaswa is the Edey claim staked on iron-bearing rocks which have no structural resemblance to the rocks of the western Michipicoten range proper, but which geographically belong with the western Huronian area.

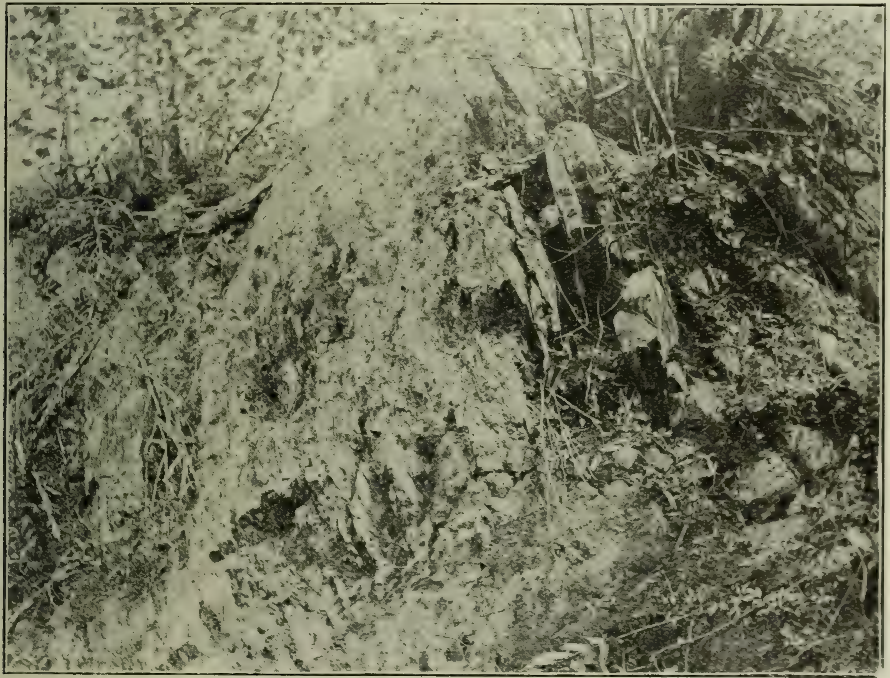
Some ten miles in a directon north 20° east of the mouth of the Pucaswa is the Lorne prospect of impure magnetite, which occurs near the shores of McDougall's lake in highly metamorphic schists, a very small inlier of Lower Huronian rocks within granite. These interesting rocks have no visible connection with either the western or northern Michipicoten Huronian areas, but I am of the opinion that they are to be connected with the latter, since they are almost on the line of the strike of the narrow belt of Huronian rocks which extend south of west from Iron lake.

The bands of richly ferruginous cherts which appear on the Gros Cap peninsula near Michipicoten harbor, and which belong with the eastern range, may be the continuation of the banded cherts of the western range which dip below Lake Superior just west of Fall creek.

SPECIAL AREAS OF IRON FORMATION

Iron Lake

The Iron lake area extends from Bole lake on the west to Red Pine point at the eastern end of MacDougall's promontory. It is the widest and longest continuous band in the district, being over two and a half miles long and having a maximum width of a little over 1,100 feet.



Iron formation, Iron lake.

It appears topographically as a relatively high range of hills of more or less regular angular outline, presenting steep cliffs relieved by talus to the south and more sloping faces to the north, and cut across by frequent valleys which represent eroded dikes or fissures. The band consists of a series of closely compressed south-dipping isoclinal folds, with minor pitches to east and west and major pitch to the east. The direction of pitch of folds of the iron formation is often difficult to discover. Actual pitching troughs or arches were not often observed in the field, and the pitch of the synclines was judged generally by the slight persistent divergence of the strike on the opposing limbs. In a general way the pitch is probably to the west near Bole lake and to the east near Van Evera's lake—certainly to the east (with high angle) near the shacks formerly occupied by the Minnesota Iron Company, and again in the same direction at a point about half way between the shacks and the western end of Minnesota bay (and at an angle of about 45°). From this point it is probably towards the east as far as the diabase dike which runs almost north and south near the foot

of Minnesota bay, and may be from the opposite direction on the opposite side. The outlet of Windigo-Weas lake into Iron lake is along an eroded diabase dike, and from the conditions of jointing seen on either side of this dike, it is presumed that the pitch is away from the dike in opposite directions. To the east of the dike the dip of the jointing planes is to the west, and west of the dike nearly vertical or possibly slightly to the east. Since in joints due to torsion the direction of the jointing plane is roughly perpendicular to the dip of the strata, and since the pitch is a form of dip, it is presumed that the direction of the pitches of the troughs are at right angles to the dips of the jointing planes and hence in the direction named.

The general trend of the Iron lake band is more or less uniform from Bole lake to the Minnesota shacks, the strike being about north 80° east. The Minnesota shacks lie in the valley formed along the eroded plain of a thrust fault. Here the beds turn sharply to the north and then north 65° east, and this general course is maintained to the point where the bands dip below the waters of Iron lake at the end of MacDougall's promontory, though numerous small irregularities and even autoclastic breccias occur. The dip is always to the south at an angle varying from 55° to the vertical.

The Iron lake band is bordered to the south by a narrow layer of quartz-porphyry schist separating it from the Doré conglomerate. This schist seldom outcrops, but its position can easily be followed by the narrow valley which runs parallel to the iron range, and which shows that erosion has eaten through the higher iron formation into the lower schists. At some points near Bole lake the iron range seems to be in almost immediate contact with the conglomerate, as no schist outcrops and the valley reduced to a minimum. To the north of the range, the bordering rocks are as a rule pinkish, greenish or yellowish felsite and quartz-porphyry schists, often silicified or carbonatized, but at one point at least amygdaloidal chlorite schists may be found in close proximity. The quartz-porphyry schist on the north side of the iron formation is lithologically almost identical with that on the south side, and it is presumed that they represent the opposite limbs of a synclinorium.

Dikes of diabase traverse the iron range at four points. One running in a direction south 70° east cuts the sediments along the north shore of Bole lake. A second running about southeast, outcrops prominently as a west facing cliff just west of the Minnesota shacks. A third with a course north and south is exposed near the foot of Minnesota bay. It appears only towards the north of the iron range, but its course southward is marked by the path of a small stream. A fourth dike is the one which follows the outlet of Windigo-Weas lake, seen in numerous outcrops to run about south 15° west.

Dimensions and Relationships of Band

The range has a width of some 460 feet on the side east of the dike, at Bole lake, of about 600 feet (possibly more) at a point about one-half mile west of the Minnesota shacks. Eastward from the fault line it gradually widens, and north from the foot of Minnesota bay has a width of 1,050 feet. From this point the southernmost part of the band disappears below the waters of Iron lake, and the northern becomes intermixed with phyllites and schists. To the west of Windigo-Weas lake and between that body of water and the main lake, the outcrop has a width of some 400 feet above water, and when it disappears altogether below the water at McDougall's promontory it has a width of 250 feet. North of the main band and running approximately parallel with it are several narrow bands, more or less persistent for a few hundred yards. These bands are the pinched-in remnants of synclines of a higher order than the main band, with which they were formerly connected before erosion had proceeded so far as it has at present. The most prominent of these is at Windigo Bones point, where the width is about fifty feet.

Lithologically, practically all the rocks of the Michipicoten iron range are represented at Iron lake. The prevailing type is a somewhat impoverished, banded chert, almost always magnetic. Towards the northern part of the range are the less weathered varieties, and true banded jaspers showing distinct separated layers of jasper and magnetite are observed in many places along this face. On the exposed southern face of the cliff to the west of Iron lake, the iron-bearing rocks are much decomposed, and in the valley below, particularly near the edge of the Doré conglomerate, consist of rusty granular or sandstone chert.

The much jointed cherts facing the water along the north shore of Minnesota bay are extremely sideritic, whereas their opposite slopes are often jaspyllitic. Coarse-grained chloritic siderites, in intimate connection with highly magnetic banded jaspers, occupy an adjoining position just west of the third dike described above, and their relations may possibly indicate that the latter is a metamorphic product of the former. The sedimentary origin of these particular coarse-grained siderites, interbanded, with the iron formation seems questionable. They may simply represent the extreme phase of carbonization of the much altered intrusive igneous rocks—dolorites or diabases which have been already described as consisting in large part of siderite or other carbonates.

Associated with the cherty ferruginous rocks phyllites occur in several places—notably in the valley between Windigo Bones point and Red Pine point, and the cherty siderites along McDougall's promontory contain so much chlorite or microcline that they become sideritic slates or arkoses.

The numerous chloritic sideritic schists interbanded with the iron formation are, I think, all of igneous origin, though some of the narrower sheets towards the north of the range may be sedimentary. These sheets are limited almost entirely to McDougall's promontory and just west of it, where by their occurrence the value of the iron formation is greatly deteriorated by lessening the amount of rock from which ferruginous material can be drawn and by preventing by their imperviousness the lateral flow of meteoric waters, since both free circulation and abundant iron formation are requisite for the development of a large ore body.

The metamorphic influence of the smaller intrusive dikes, etc., upon the iron formation is not pronounced. The contact phenomena are comparatively slight, being shown only by the greater amount of magnetite close to the dike than at some distance from it. On the other hand, the propyllitization of the narrow dikes by solutions derived from the iron formation is general, and will be discussed later. The wide boss of magnetic diorite existing north of the Algoma Commercial Company's shacks on Minnesota bay has greatly altered the rocks into which it has been intruded, which for over a quarter of a mile north of the boss strongly deflect the magnetic needle. The altered rocks consist chiefly of magnetic epidote schists, with probably some magnetite amphibole schists. They are apparently often altered sideritic slates, though much of them may be altered igneous schists, and only a comparatively small portion have been proved to be undoubtedly sedimentary. The origin of most of these magnetite bearing rocks is difficult to decide definitely, owing to the extreme degree of metamorphism and the somewhat confused field relations.

South of Van Evera's lake and near Bole lake the banded cherts are highly ferruginous. In the ferruginous cherts south of Van Evera's lake occur small pockets six or seven inches wide of a hydrated hematite. On these, test pits were sunk by the Minnesota Iron Company, but the iron improved neither in quantity nor quality in descending. A great deal of test-pitting and stripping has also been carried out at Bole lake, but these operations were not conducted along the contact with the overlying formation, apparently the most likely spot at this locality for the occurrence of an ore body.

Ore Showings

Along the range between the Minnesota shacks and Iron lake a considerable amount of stripping has been done, much test-pitting carried out, three tunnels run and one shaft sunk on small pockets of ore visible on the surface.

The entrance of the first tunnel is about 200 feet northeast of the shacks. The tunnel runs to the northeastward into the pronounced west facing cliff. At the entrance to the tunnel soft bluish hematite, much mixed with chert, appears on the walls. About seventy-five feet higher up the hill, and some fifty feet or more farther east, is a second tunnel which enters the hill in a southeasterly direction, and then turns northeastward. The ore showing here is of better quality than at the lower tunnel, and consists of bluish soft hematite, with specks of quartz. The ore body apparently has a vertical thickness of at least twelve feet, and becomes less ferruginous and merges into the cherty rocks above, which contain comparatively little iron. Downward the face of the hill is covered with talus and the extent of the ore body in that direction is not traceable. I understand from Mr. Robert Murray, formerly in charge of the exploration work carried on at Iron lake, that the ore became more silicious away from the outcrop. The third tunnel is excavated into the hill at a point about 250 yards east of the other two, just north of the trail, which connects the Minnesota shacks with Minnesota bay. It was carried into the hill for a distance of 160 feet. Pockets of good soft ore (hematite) occur for this distance, but are much mixed with chert. The tunnel has a height of eight feet above the shelving bank, and a width of about six feet, and these dimensions may be said to mark the limits of the ore, at least above ground. Above the ore and standing in marked contrast is an area of almost pure white, very quartzose chert, showing no banding. The ore itself is soft reddish hematite, and with some botryoidal and rusty hydrous hematite.

Analyses were made of various specimens of ore, and of enclosing iron-bearing rocks from the Iron lake area. The results of the analyses follow below. Number 1 is an iron ore from the upper tunnel (second tunnel above described), and may be said to represent one of the relatively rich ores of this locality. It will be seen that as far as sulphur and phosphorus are concerned, the ore is of Bessemer quality, but it is low in iron content. However, it is a soft ore, and if it existed in quantity, would certainly be marketable. Number 2 is a soft and often very red limonite from the tunnel on the trail between Minnesota bay and the shacks (third tunnel above described). Number 3 is a soft ore jasper from the same tunnel. In the field the rock is very irregularly banded, and consists of pinkish chert gathered in irregular areas with impure purplish chert and streams of rich dark red hematite. Number 4 is a jaspyllite from McDougall's promontory, consisting of interbanded pinkish, somewhat crystalline chert, reddish very silicious ore and streaks of specular hematite. Number 5 is a pyritous cherty siderite of an opalescent bluish gray color, from flank of hill facing Minnesota bay. Number 6 is much the same only darker in color, from Red Pine point, while number 7 is from a boulder of cherty siderite found in the drift on the portage between Iron lake and Minnesota bay.

	Fe.	P.	S.
No. 1	59.52	.04	.02
" 2	54.76	.035	.02
" 3	36.03	—	—
" 4	21.14	—	—

	SiO_2	FeO	Fe_2O_3	CaO	MgO	CO_2	S
No. 5	84.76	6.82	2.80	trace.	.28	3.75	.70
No. 6	81.86	9.97	1.53	trace.	.30	5.49	.63
No. 7	62.78	17.87	5.17	trace.	1.42	12.11	....

A Promising Prospect

It has been a matter of general comment among geologists and mining men generally on the south shore of Lake Superior where large ore bodies have long been developed, that these bodies occur in places where certain definite geological conditions have been realized. These conditions have been enlarged upon by various geologists,[15] and it is unnecessary for me to more than mention them here. The presence of an impervious basin beneath the ore formed either by igneous schist, sedimentary slate or eruptive rock, is a striking feature generally observed in connection with all large ore bodies in regions of similar geological conditions as exist in Michipicoten. This basin may be a pitching trough sloping from two directions to a common centre, formed by transverse folding of longitudinal folds, or this larger trough may be divided into several smaller troughs by transverse dikes. Contact planes, much fractured iron formation giving free passage of circulating waters, a wide outcrop of iron formation, and in general a much decomposed and deferruginized surface outcrop, are generally also connected with iron ore deposits of this sort, when of economic importance.

It will be seen that at Iron lake we have ideal conditions for the development of ore bodies. *First,* an abundant iron-bearing formation. *Second,* pitching troughs on an impervious basement of various green schists. *Third,* numerous secondary structures developed, faulting, jointing, brecciation, etc., allowing free circulation of iron-bearing solutions and permitting the enrichment of the ore bodies. Large quantities of ore are certainly not found at the surface, and if they exist, as seems probable, they are either beneath the rock surface or else are covered by sand or other drift or talus. As the truncated isoclinal folds dip to the south, it would appear preferable to conduct exploration for ore bodies from that side. The cross diabase dikes act as barriers to the iron-bearing waters and cause the depositions of ore where the trough pitches towards the dike, hence there would be near the dike a position on the south side which would seem especially favorable. There are many such positions which combine these favorable conditions at Iron lake.

The Iron lake range is on the whole an exceedingly desirable and likely prospect, and there is apparently no reason why ore bodies should not be found there.

The Katossin Claims

The bands of the Helen formation on which the Katossin claims are staked, are situated north of Iron creek and of Clearwater pond. It has already been mentioned that they are continuous for about one-half mile, and that they represent the opposite limbs of a synclinal fold of a second or third order. At the surface neither band is of great width, seldom exceeding twenty-five yards across. They are both complexly anticlinal in structure, and the north band, at least, shows green schists overlying on both sides. From this it is presumed that the schist occupies the top of the trough between the two bands, though comparatively few outcrops either of schist or of Helen formation appear above the sand-plain, and it is difficult to make sure on this point. The extent of the iron formation, particularly adjoining the north band, was traced by magnetic observation, and was found to continue for thirty or forty yards at least on either side beneath the schists. Moreover the different outcrops were connected in the same way along the line of strike, although the north band was not actually joined to the south one by this means.

Lithologically, the north band consists chiefly of pyritous, very magnetic, cherts, often rusty and impoverished, and of interbanded crimson jasper and bluish magnetite or specular hematite. The latter, which may be called jaspyllites, sometimes contain so much iron ore as practically to be considered an iron ore. The south band is made up of much the same material, though rather more decomposed and less jasper-like.

15 See "The Exploration of the Ontario Iron Ranges," by A. B. Willmott, Journal of the Canadian Mining Institute, Vol. VII, pp. 257-261.

Analyses were made of several specimens from the Katossin claim, all from the north band, and the results are given below. Number 8 and Number 9 are rich magnetic cherts, and Number 10 is one of the very rich jaspyllites.

	Fe.	S.	P.
No. 8	43.17	.05	.093
" 9	40.39	.06	.04
" 10	58.48	.02	.035

The general strike of both the north and south bands is north 85° east, and the dip both to north and south, though generally the latter.

Basic dikes certainly traverse the south band and probably the north one also. The troughs pitch sometimes at a high angle, sometimes at a very low angle to the eastward, so that closed pitching troughs favorable to ore-deposition are common, and secondary shearing along the bedding planes has produced micaceous specular hematite. Schists usually of the fine-grained chloritic type, are found freely pinched-in with the iron sediments, and it is not always possible to tell the relative age of the iron formation and of the schists It is also impossible to even attempt an estimate of the thickness of the beds. The minimum may be set at ten feet, and is probably many times greater.

Katossin claim, Iron river, showing anticlinal strata.

On the whole from surface examinations the Katossin claims do not seem at first sight a promising prospect, but when it is remembered that the entire trough between the bands is probably occupied beneath the sand and schist (certainly not of great depth) by an unknown and perhaps great thickness of iron sediments, the economic possibilities of the claims seem more favorable.

West of the Dog River

About one-quarter of a mile north of the east end of Pitch Pine lake beds of Helen formation appear above the general low ground, and are interruptedly continuous almost to the Dog river, a distance of about three-quarters of a mile. The

ferruginous rocks form a comparatively narrow band seldom, if ever, exceeding thirty-five yards in width, bordered to the north by soft chloritic, sometimes nacreous felsitic or quartz-porphyry schists, and to the south by black phyllites or quartz porphyry schist.

The exact structure of the band was unidentifiable, but apparently it consists of a series of very closely compressed isoclinals. The strike varies from north 65° west towards the eastern end of the band to north 85° west at the opposite end. The dip is generally vertical, but is occasionally to the south.

The rocks consist entirely of rusty banded chert, often pyritous and occasionally magnetic. The quartz-porphyries associated with and bordering the iron formation are greatly silicified, and in places carbonatized. These altered schists have often a strong lithological resemblance to the Helen sediments. The phyllites which appear along the south side of the band at one or two points, are black, fine-grained, and very regularly crenately-banded.

Paint Creek and Mount Raymond

The Paint Creek band starts as a number of narrow lenses in the mashed quartz-porphyry north of the marsh which lies just east of the portage from the Frances mine to Paint lake, and is continuous as one larger band and several smaller unimportant sub-bands almost to Paint lake, a distance of over a mile, where it is cut by the granite boss forming mount Raymond. Beyond mount Raymond it bends sharply to the northward and may be traced as one wide mass for over half a mile. The range appears as a low line of hills to the west gradually rising to mount Raymond, which has an altitude of about three hundred feet, then dropping slowly towards the north. The iron formation west of mount Raymond will be described as the Paint Creek band, while north of mount Raymond will be considered as the mount Raymond band.

The Paint Creek beds have a maximum width towards the west of one hundred and sixty feet, and are generally much narrower, but to the eastward they rapidly widen and have near mount Raymond a width of over seven hundred feet. Towards the west quartz-porphyry schist of the underlying green schists strongly predominates over the iron-bearing rocks. The latter appear at intervals within the schists only as narrow, shallow outcrops, which represent the eroded remnants of former deep synclines. As the range increases in height to the east, the quartz porphyry schist becomes less important in the belt, and finally dies out altogether.

The strike of the range varies from south 80° west on the west to north 80° west on the east. The dip of the beds varies slightly from the vertical both to north and south, and the pitch is probably for most of the length of the trough to the east though from the relations of the parallel range at the Frances mine it would seem to be to the west for at least part of the distance. Three visible cross dikes of diabase traverse the range, and as mentioned above, a wide boss of granite cuts it off near Paint lake.

The prevailing type of rock is a rusty impoverished granular or banded chert, often pyritous, occasionally sideritic, and sometimes magnetic. The eruptive granite of mount Raymond has altered the Helen sediments both physically and chemically. The beds have been much contorted and brecciated. The banded ferruginous chert has been changed to magnetite actinolite schist, and magnetite grünerite schist. Small contact metamorphic deposits of very impure magnetite, which contains 21.42 per cent. metallic iron, have been formed near the edge of the boss in the porous iron formation, and a wide quartz vein which is highly pyritous and slightly auriferous, has developed in close proximity. This quartz vein is at least fifty feet wide and probably three hundred yards in length, though this could not be definitely ascertained. It was probably formed by the metasomatic impregnation of the iron sediments by quartz bearing slightly auriferous pyrites, and probably some other sulphides, brought by hydrothermal waters marking the dying stage of volcanism.

The islands of the western part of Paint lake and the eastern mainland opposite them are composed of hard dense, fine-grained garnetiferous zoisitic schist, resembling a hornfels in the field. It is often rusty, due to the oxidation of the large amount of iron pyrites which it contains. This rock, on account of its megascopical, lithological resemblance to unquestionable clastic sedimentaries and because of the absence of any definite igneous characteristics, when studied microscopically has been considered as a much altered slate, but it is possible that it may be more correctly a highly metamorphosed chloritic schist.

The structure of the complicated mass of rock near mount Raymond is exceedingly difficult to study, owing to the confused nature and scarcity of the outcrops and the extremely thick and tangled forest growth which completely clothes the country in this vicinity.

Ore Possibilities

The low-lying shores of Paint lake just to the south of mount Raymond are covered with a deposit of mossy peat, two to three feet thick, beneath which is a thin layer of bog iron ore formed from the leaching of the ferruginous sediments on the hills above. The deposit is too small to be of much economic value. The ore contains 54.6 per cent. of metallic iron, .08 per cent of sulphur, and .016 per cent. of phosphorus.

It is possible that a large ore body may exist to the south and west of the granitic boss of mount Raymond, but I do not think so, as the iron sediments are mostly of the altered character upon which meteoric waters do not easily act to allow the formation of a large ore-body. Westward in the narrower part of the trough there is not a sufficient thickness of iron formation left after the extensive sub-aerial denudation to have ever had an ore-body beneath it.

No part of the Helen iron formation in northern Michipicoten is more difficult to study, and yet more interesting in its field relations than that part of it immediately north of mount Raymond. As has been explained, mount Raymond is a wide, intrusive granite, and quartz-porphyry granite boss, and this intrusive granite also borders the iron range both to east and west. The influence which this enormous intrusion has had on the surrounding rock is most profound, and is even more pronounced than south and west of mount Raymond.

These rocks have been so intensely corrugated and even brecciated that their former bedding planes have been entirely lost or rendered impossible of recognition. The strike of the beds, if such it can be called, or more correctly the trend of the range, is extremely irregular and is always changing. Roughly, it is almost north for about 600 yards from mount Raymond, then northwest for 200 or 300 yards. Beyond this point the formation is impossible to follow, partly from the thick nature of the forest growth and the large amount of fallen timber, and partly from the scarcity of reliable outcrops. It is possible that the greatest part of the range is covered by more recent schists. The dip is decidedly uncertain, but is generally vertical, sometimes with a slight inclination to the east.

The whole appears to be a compressed compound synclinal fold pitching to the north, as judged from the really few evidences in the field. The width is for the most part great, being rather over 640 feet for the first 600 yards. Beyond this point the width of the much drift-covered band could nowhere be accurately ascertained.

Wide greenstone and quartz-porphyry dikes cross the belt towards its northern limit, and may have acted as barriers to north-flowing iron-bearing solutions, but the nature of the rock, particularly to the south near mount Raymond, being resistant to the attack of the weathering agencies, is prohibitive to the production of an extensive ore-body. While this does not apply so much to the northern part, it is at least an important factor in its consideration.

Morse Mountain

Morse mountain is an irregular shaped hill some 200 feet in height lying about one-quarter of a mile southeast from Heart mountain and rather a greater distance southwest of Cushing lake. Outcrops of solid rock on its southeastern, southern and western faces are entirely of a soft chloritic schist, and on its northwestern face of Helen iron sediments. The summit of the hill is almost wholly drift-covered, the few outcrops shown being small and unsatisfactory. Towards the northwest side these seem to be mostly of rusty chert, and towards the opposite side of chlorite schist. From the northwestern corner of the hill a gradually dropping tongue-like ridge stretches to the northeast between Heart mountain (from which it is separated by a deep valley) and Cushing lake.

The northwestern face of the hill shows the Helen formation outcropping for nearly a quarter of a mile across the strike with three narrow sheets of a granitic porphyry intercalated. On the opposite side of the hill where the green schist outcrops, there is only one sheet of porphyry seen. The tongue-like hill is, close to Morse mountain, composed entirely of rock of the iron-bearing foundation, but at some 500 yards along the strike this dies out in "tails" of chert in the schist.

There are three ways of explaining the rather strange field relations. First, that it is a pinched-in synclinal fold or series of folds younger than the enclosing schists; or second, that it is a southerly pitching synclinal fold or series of folds, in which the chloritic schists to the south are younger than the iron formation, and the latter in turn younger than the schist in which it dies out to the north; or third, that it is a northerly pitching trough with exactly the opposite relations. The second explanation seems to be much the most likely on account of the rather sudden appearance of the iron formation on top of the hill and on account of the tail-like disappearance to the north. However, this is inadequate proof and needs substantiation by further evidence.

The iron-bearing rocks of Morse mountain consist of rusty granular chert and of more or less ferruginous banded cherts, both much impoverished and weathered. The intrusives of Morse mountain are all of the granite-porphyry type, intruded parallel to the dip of the beds through the line of weakness at the base of the isoclinal folds.

Morse mountain has in its favor as a prospect the widest continuous outcrop of Helen iron formation exposed in the northern part of Michipicoten, with ferruginous though now much impoverished rocks, upon which surface water would easily act, and in places a brecciated structure allowing free circulation.

East of Heart Lake

The narrow belt of iron range rocks which occurs just east of Heart lake shows some interesting metamorphic changes. The belt is apparently the small pinched-in truncated remnant of a former deep synclinal trough, which has a general strike of north 30° east, with variations to north 70° east, and to almost north and a prevailing southeasterly or easterly dip of 65° to 85° or even vertical.

The band which has an average width of about forty feet, is terminated to the southward by a large, fine-grained greenstone boss, and to the northward by a portion of the quartz-porphyry edge of the great post-Huronian acid eruptive mass of northern Michipicoten.

Lithologically, away from the influence of the intrusions the rocks consist chiefly of rusted banded chert, and at one point a very small deposit of bog ore exists in a valley between two knobs of iron formation. Near both the quartz porphyry and greenstone the banded cherts are changed by contact metamorphism. The greenstone produces a coarse-grained banded magnetite-hornblende schist, and the quartz-porphyry a somewhat fine-grained hornblende schist.

North of Narrow Lake and Lake Charlotte

Very similar alterations of the iron formation to those east of Heart lake may be seen in the several narrow parallel bands of iron formation which run along the northern shore of Narrow lake and lake Charlotte, the principal band forming in great part the face of the cliff which rises abruptly along the northern shore of the two lakes and is continuous as the northern edge of the valley which connects them. This main band, though never more than fifty feet wide and generally much less, is more or less continuous all the way from a point about half-way between the Dog river and Narrow lake to the northern bay of lake Charlotte, whereas the smaller bands are mere lenses continuous for only a few feet. Structurally they consist of closely plicated, compressed synclinals of almost vertical dip, and with a fairly regular general but very devious and erratic local strike.

The bands run roughly parallel to the contact of the Lower Huronian series with the post-Huronian granites and rather more than a quarter of a mile from it. South of the actual contact with the unbroken mass of post-Huronian acid eruptives numerous narrow sheets of quartz-porphyry and felsite are intruded parallel to the foliation of the schists, and the bedding planes of the iron formation. Besides these sheets of acid eruptives, basic greenstone dikes traverse the range at various points. Their metamorphic effect is less pronounced than that of the quartz porphyries and felsites. By far the greatest part of the iron formation has been more or less thoroughly changed. Sometimes interbanded black or white cherts are seen, or very rusty recrystallized cherts, but the commonest type is a more or less amphibolitized schist. This rock, which consists chiefly of hornblende, epidote and quartz, is remarkable in containing very little magnetite or even none at all. Presuming that all the minerals of this rock are authigenous, it may be supposed that this hornblende-epidote schist resulted from the metamorphism of a carbonate, rich in lime and magnesia and containing comparatively little iron, with probably some clastic chlorite.

The chloritic schist adjoining the iron formation has also undergone great change, being converted to epidotic and micaceous schist. The boundaries of the metamorphic aureole are exceedingly irregular, sometimes rocks near to the intrusive granite being practically unmodified, while others more remote have suffered complete alteration.

Magnetic Point

Magnetic point on the north shore of East Kabenung lake is a short bean-shaped strip of land connected with the mainland by a narrow neck. Along the exposed southern face of the point runs a line of low cliffs composed of the Helen sediments. The northern face of the ferruginous band is for the most part drift-covered, but in a few places soft phyllitic schists (very probably fragmental) outcrop at a distance of about thirty yards back from the water, giving a maximum width to the belt of at least thirty yards. Still farther north on the mainland only a few small exposures of solid rock are visible, and these are mostly of schist containing narrow bands of magnetic chert. In taking our magnetic readings while traversing the bands the compass showed a phenomenal deviation irregularly both to east and west for over a quarter of a mile north of the water. It may be presumed that lenses at least of iron formation occur within the schists for this distance, though the surface covering of clay and moss precluded actual observation.

The Magnetic point belt outcrops for some two hundred and twenty-five yards along the point itself, and appears on a small island just off the shore and on several adjoining islets still farther east. The bands are a continuation of others occurring in schists and phyllites for over one hundred yards across the strike on the mainland to the west.

The iron-bearing rocks of Magnetic point are composed almost entirely of magnetite-grünerite schist. Sometimes this may consist of wide lenses of a somewhat

magnetic granular chert always containing a few needles of grünerite, and but slightly interbanded layers of sparkling coarsely crystalline magnetite and light yellowish gray-green grünerite, and finally of bands three to four inches wide of almost pure magnetite. Sometimes the magnetite-grünerite schist contains so much magnetite, especially where the wider layers of magnetite occur, that it is practically an iron ore. The beds of iron formation at Magnetic point lie quite one-half mile south of the main mass of intrusive granite, and it is unlikely that this caused the pronounced metamorphism of the iron sediments. This great transformation may be partly due to the intrusions of basic igneous rocks which at least occur, though to what extent is not known, but it is probably mainly the result of the intense dynamic strain which the rocks in the immediate vicinity have undergone.

Analyses were made for iron, etc., of several specimens of the iron-bearing rocks from Magnetic point. Number 11 is a specimen of a highly magnetic grünerite schist, and Number 12 of a coarsely crystalline magnetite from one of the narrow bands above described.

	Fe.	S.	P.
No. 11	43.35	.009	.073
" 12	64.31		

The strike is decidedly irregular, the beds being often brecciated. The dip is towards the south at an angle of 75° to 85°. Magnetic point is probably at about the centre of a crumpled synclinal fold, towards which the troughs pitch from either side. The narrow bands of Helen sediments of Magnetic point and of the still narrower lenses farther north, are the bottoms of synclinal folds of a high order—all that remain of what were once parts of a wide belt of iron sediments, probably of great thickness.

Evans Creek Area

The Evans creek area lies close to Evans creek and to the northeast of Godon lake. The area contains two pronounced bands, and possibly a third band of iron formation, which run generally parallel. The more southern of the two pronounced bands forms a decided ridge some two miles northeast of Godon lake, while the more northern band lies about half a mile farther northeast on the northern side of Evans creek. Just south of the creek a few scattered outcrops occur along the flank of a high drift-covered hill. These may represent a separate band or may properly belong to the northern band a few yards distant on the other side of the creek.

The rocks consist of evenly banded highly magnetic chert, and of rusty saccharoidal chert. On the northern band the main outcrop of the iron formation is rather less than a quarter of a mile long and with a maximum width of about 175 feet. It rises as a low hill with abrupt cliffs facing the creek on the southwest side. To the northeast it is bordered by a sand-plain, in which it also disappears to the southeast. To the northwest near where it dips below the sand-plain, it is much mixed with a soft chloritic schist. At three-quarters of a mile farther to the west-northwestward an outcrop of iron formation appears above the sand-plain, and rather less than a mile to the east-southeast a lens of whitish gray and rusty chert occurs in schist. This lens is about forty feet wide, and about four times as long. The strike of the band varies from N. 50° W. to N. 80° W., and the dip to the southwest at from 59° to 70°. The band is supposed to be a compressd synclinal fold, but no direct evidence bearing on this point could be obtained. The more southern band is much longer and more continuous than the northern band. It runs somewhat brokenly for more than a mile and a quarter, and is cut off by diabase to the east-southeast, and disappears below the sand-plain at the edge of Evans creek in the opposite direction. Its width is for the most part somewhat uncertain, but at one point at least it is not less than 250 feet across. Structurally and lithologiclly, it may be considered as similar to the northern band.

FRANCES MINE AND NEIGHBORHOOD

The Frances mine range is an irregular-shaped hill presenting steep talus-relieved cliffs to the north, northwest and east, and grading off to the southwest and northeast in long sand-covered slopes.

The only solid rocks appearing in situ on the Frances mine hill are of the Helen iron formation, and these consist of impoverished banded chert, very ferruginous banded chert or soft ore jasper, granular pyritous chert, much oxidized sideritic chert, and few seams of hematite. The total outcrop has a maximum width of 935 feet and a length of 1,375 feet. The rocks are well exposed both naturally and artificially, and comparatively easy of field study.

The iron sediments have been crumpled into a series of closely compressed north dipping isoclinals, each with a decided pitch from east and west, converting them into deep canoe-shaped troughs. These relations have been proved by ample field evidence supplemented by the results of several drill holes. The strike makes many variations from regularity, but its average may be said to be about north 85° west. The dip with one exception is always to the north at a high angle or vertical. By a careful study of the strike all over the hill it was observed that both on the east and west sides the strike of the upturned beds converge towards each other, as would naturlly be expected in synclinal folds. It was also noticed that the angle of convergence was much more open on the west side than on the east, showing a steeper pitch of the troughs on that side of the hill. At the Frances the beds are much contorted, and in many places brecciated—the results of long continued dynamic strain.

Several small and unimportant bodies of iron ore occur on the surface, and were the means of first drawing attention to the Frances. All of these ore-bodies are situated on the top of the hill, and are merely surface deposits. The ore is generally a rich, compact, soft hematite. It is sometimes a blue-black slate ore, and again a hydrous hematite, probably göthite. The value of even these small deposits is lessened by numerous small horses of jaspery chert and geodes of quartz crystal. The larger of these lenses has a length of forty feet, and a greatest width near the middle of nine feet. The rock underlying the iron formation is a soft chloritic schist, as discovered by test pits and drill holes and as exposed at several places to the south and north of Frances mine hill.

We have at the Frances apparently excellent conditions for the formation of a large ore body: to recapitulate, a series of closed north-dipping, canoe-shaped troughs, having a greater pitch from the west than from the east, lying on an impervious basement of green schist, a large amount of iron formation from which to draw material, and this formation brecciated and open to the influence of oxygen and iron-bearing solutions.

From a careful examination of the hill it would seem apparent that the best point at which to carry out prospecting work is on the north side, since the prevailing dip is in that direction, and the best location of a drill hole would be towards the western end of this side, since there is a steeper pitch on that side, and hence the deepest part of the trough containing most of the ore-body might be expected in that position.

During the time the prospect was being worked by the Algoma Commercial Company six drill holes were completed and two more started, the last three being on the north side of the hill. Two of the others were run from the foot of a shaft sunk on one of the small ore lenses already mentioned. I understand that these were drilled, one horizontal to prove the length of the lens of ore, and the other vertical to test its depth. Both soon got out of ore. Had the latter been continued deep enough, it would doubtless have struck ore again, but even if it had, the proof obtained would have been of little value, because it was too far east to have reached the main body of ore, and would not have shown the lateral extent, which in such closely compressed troughs as occur at the Frances is an important feature.

The other three drill holes were carried in either on the southern or eastern side.

The drill hole which was completed on the north side of the hill, was successful in locating ore, and I am informed that at a depth of 521 feet a considerable stratum was entered.

Several specimens of iron ore from the small lenses on top of the hill were analyzed, which proved it to be for the most part of fair quality. Number 13 is a soft, bluish red ore; other specimens were of a somewhat harder variety.

	Fe.	S.	P.
No. 13	62.46	.02	.02

Brotherton Hill

Apparently Brotherton hill is structurally the same as the Frances hill—that is, it consists of a series of closely compressed, canoe-shaped troughs with dip at high angles to the north or almost vertical, and with a general strike of about N. 75° W. The surface outcrops are, however, not nearly so good and those seen are not as favorable as at the Frances, and on the whole Brotherton hill may be considered an inferior prospect compared with the Frances. The total outcrop of the Helen formation is rather over 1,800 feet long, and is at least 900 feet wide at its widest part, but is generally much narrower.

The rocks of the iron formation at Brotherton hill consist chiefly of banded grayish, rusty weathering chert, very rarely highly ferruginous chert, granular pyritous chert, and fine-grained blackish chert. At the southeast corner of the hill and separated from the highest part of it by a cedar swamp, is an outcrop of a peculiar massive highly ferruginous pyritous rock which is probably a phase of the iron formation. On the south side of the hill evenly banded soft grayish phyllites occur close to the cherty rocks. On the north side there are outcrops of chloritic schists, but none in immediate contact with the iron formation.

A wide dike of much altered diabase crosses the hill diagonally, and appears to send sheet-like offshoots in between the beds of iron formation, or at least is in part parallel with the beds rather than traversing them. The widespread presence of this altered diabase materially diminishes the economic possibilities of Brotherton hill:

First, by its impervious nature preventing free circulation of iron-bearing waters.

Second, by its greatly decreasing the amount of iron-bearing formation, from which to draw ferruginous material.

South of Kabenung Lake

The broken bands of iron formation lying to the east of No-Fish bay are almost unworthy of consideration. Roughly speaking there are three narrow bands, never continuous for more than a few hundred yards, and untraceable for much longer distances. The strike is in general N. 30° E., though there are numerous slight departures from this course. From the disparate and irregular distribution of the outcrops taken in comparison with the comparative regularity of the strike and dip, it is presumed that there must be marked and rapid variations in the pitch of the folds to have given the present field relations. All outcrops are apparently in general synclinal, and were evidently once part of a continuous synclinorium.

The southwestern band, if so broken a series of outcrops can be so connected, is the most important of the three. This band, though the outcrops are for the most part narrow and inconspicuous, shows along its course several extraordinary fairly wide, lens-shaped masses of very rusty granular chert suddenly rising in castle-like form above the low muskeg. One of these monoliths, about 300 yards east from the narorws between Big island and the mainland of Kabenung lake, has a width of at least 90 yards, but dies out at less than 175 yards in green schists. This abrupt appearance and disappearance of knobs of the iron formation is very typical of this part of the area.

The belt of iron formation which is continuous for over one-half mile from the foot of Perry's bay of Kabenung lake to the south of White Water-Lily pond is also unimportant, having a maximum width of only thirty-five yards and dying out in quartz-porphyry schists to the eastward. The dip was observed to be about vertical or with very slight inclination to the south, and the average strike about east with variations from S. 55° E. to N. 80° E.

Lithologically, this portion of the Helen formation shows rusty banded cherts, banded jaspers and hard black chert. With them is associated black phyllite, and the formation is bordered by various sericitic schists. On one of the cross valleys, cutting the low ridge of hills, which represents geographically the Helen formation, and running at right angles to the main axis of White Water-Lily pond from its western end, some thin beds of bog iron ore were discovered. This deposit is small and local, and hence not of much economic value.

The belt which runs eastward along the low rise from the entrance of Elmo creek into lake Elmo is continuous for over one mile, dying out at either end in "tails" in mashed felsites and quartz-porphyrics. The band has for the most part a uniform strike, but shows major irregularities from north 80° east to south 75° east, besides numerous smaller contortions; and even breccias occur. It is of extremely uncertain width, being over a hundred yards across at one point and at a very short distance beyond rapidly narrowing to less than one-half of that width.

Lithologically, the iron-bearing rocks consist of interbanded chert and magnetite, and of rusty granular chert. Beds of chloritic green schist of uncertain origin are in some places interstratified, and very frequently mashed quartz-porphyry appears in connection with it. The latter is apparently older than the iron formation, and from its widespread occurrence, associated with the iron sediments, it is judged that erosion has removed by far the greatest portion of the iron formation, laying bare the underlying material. The lake Elmo band is thus of small commercial value.

Leach Lake Bands

Of the numerous synclinal bands and sub-bands once part of a wide synclinorium, occurring to the east of Leach lake, only three need be considered in a detailed way. These are bands 2, 3 and 4, which, uniting in a high hill about one-half mile to the northeast of Leach lake, diverge towards the southeast as V-shaped, prevailingly southeasterly pitching troughs. They are represented topographically by steep hills of irregular outline separated by deep valleys marking where erosion has cut through the iron formation and attacked the soft underlying schists.

The rocks of the Leach lake belt have a wide lithological variation, and show almost every phase of the Helen formation. They consist of rusty, sometimes highly magnetic, banded chert, often soft ore jasper, sideritic and pyritous chert, rusty quartzitic and granular chert, amphibolitic schist, and of small bodies of hydrous hematite and of silicious magnetite.

Band 2 is a canoe-shaped trough dipping to the southwest at a high angle, or standing vertically, and having apparently a major pitch towards the southeast. The iron formation is well exposed, and is seen to be bordered on either side by fine-grained chloritic schists. The band has a length of about 1,100 feet and dies out in lenses in schist at both ends, and is partly covered by sand-plain to the southeast. It has a maximum width, at about 100 yards northwest of the township line, of 225 feet. This width diminishes in either direction away from the maximum point and has an average of about 100 feet. The strike is as a rule uniform, running about northeast. The chert often shows an obscure lensoidal banding which may represent a friction breccia.

Band 3 is much the most prominent of the Leach lake bands, and is continuous for about a mile and a quarter. Towards the northwest the belt is narrow, having an average width of less than 75 feet, but at some 500 yards southeast of the point where it crosses the township line, it rapidly widens to 300 feet and in some places even

more, maintaining this width for almost one-half mile. Lithologically and structurally it is practically a repetition of band 2, but it was noticed that the rocks were rustier, more decomposed, less magnetic and more brecciated in band 3 than in band 2. Starting from its northwestern extension the strike varies from south 55° east to south 65° east, as far as a point some 500 yards beyond the crossing of the township line, where it changes more to the east and finally slightly to the north of east at its point of disappearance. The major pitch of the trough is probably towards the southeast and east, and doubtless there are several minor pitches in the opposite direction not shown by the field relations.

About one-half mile east of the township line a wide dike of greenstone cuts diagonally across the upturned beds, and as this dike is approached from either side, the iron-bearing rocks become highly ferruginous and locally so much so as to be called iron ores. At this point from various field relations it seems probable that the pitch of the syncline is from either side towards the dike, giving conditions fit for the formation of an ore body on either side. Several small ore bodies actually occur on the surface. One of these, an impure hydrated hematite, borders the dike on the west side. Two others on the east side of the dike occur close together and may in reality be one deposit. The most westerly is at least forty-five feet long and slightly narrower, while the other is apparently of much smaller dimensions and is as well much mixed with chert. The ore is a silicious magnetite not of very high grade, as shown by the following analyses:

	Fe.	S.	P.
No. 15	54.60	.08	.029

These lean ores are indicative of possible greater quantity and of better quality lower down the trough.

These deposits are known as Scott's prospect, and in the autumn of 1902 some preliminary exploration was done by the Algoma Commercial Company at this point, and several small houses erected. See sketch at page 336.

Band 4 is, in its geological structure and lithology, similar to bands 2 and 3. It merges with band 3 towards the northwest and dies out abruptly to the east. It has a total length of almost one mile, and an uncertain width varying from less than 75 feet to over 200 feet. The strike changes from south 65° east, towards the western end of the band to slightly north of east at the other end.

Sub-band A is an offshoot from band 3 at a point some 700 yards east of the place where that band crosses the township line.

Though the rocks of the Leach lake bands are rather poorly exposed, owing to the amount of drift on the hillsides, still for the most part the outcrops are sufficiently good to enable one to understand the field relations. Before the forest was so completely removed by fires this would not have been so easy a matter, for to the eastward, along the continuation of sub-band A, the forest growth is so thick and the few outcrops so small as to make the field study most difficult and unsatisfactory.

East of Godon Lake

About a quarter of a mile northeast of the northeast corner of Godon lake there are two low hills of iron formation. The crests of the hills are about 150 yards apart, and a shallow valley intervenes between the two. This low valley may indicate the presence of schist, but if it does not, and certainly no outcrops of schist are visible, then the total width of iron formation exceeds 150 yards. The band narrows to the southward, but is continued brokenly to the base of Diabase hill—a distance of about three-quarters of a mile. The iron formation comprises chiefly unbanded varieties of very pyritous and often rusty cherts, and very quartzose cherts. Very small deposits of bog iron ore occur near the north of the band. A specimen analyzed as follows:

	Fe.	S.	P.
No. 16	52.78	.14	.037

East of Pyrrhotite Lake

The occurrence of a deposit of magnetic pyrites or pyrrhotite lying to the east of Pyrrhotite lake and connected to it by a narrows, is scientifically exceedingly interesting as exhibiting a phase of the Helen formation in which the sulphide is the predominating mineral rather than the accessory. The dimensions of the deposit could not be accurately ascertained, owing to the amount of drift covering, but the Helen formation at this point has a maximum width of at least 50 feet and is continuous for quite 200 feet and probably more beneath the drift-covered hill to the southeast, though of course the sulphide deposit is much smaller. The deposit is simply a highly pyritous and pyrrhotitic chert, becoming rusty and much less metalliferous along its course to the southeast. Sometimes it consists entirely of pyrite and pyrrhotite with probably some magnetite, or again chert predominates. In places the sulphides are oxidized, producing a rusty "iron hat" of limonite.

A very rusty, much silicified, felsite schist borders the band to the northeast and a weathered sideritic schist to the southwest. This sideritic schist is also interstratified with the pyritous chert along its southeastern extension. The pyrrhotite does not carry nickel. The rusty limonite gives the following analysis:

	Fe.	S.	P.
No. 17..	50.69	.72	.056

Some preliminary exploration work was carried out by the Algoma Commercial Company both east of Godon lake and at the pyrrhotite-pyrite deposits in 1900.

Eccles Lake Claims

The Eccles lake claims are thirty-two 40-acre claims situated east of the Magpie river. They stretch from north to south for a mile and a quarter at a distance of 2 miles to 3¼ miles above McKinnon's bridge. The claims were staked because of the occurrence of certain bands of the Helen formation within the green schists of the area covered. It has already been mentioned that geographically they belong with the eastern range, though they have a geological connection with the northern range as well.

The whole area is more or less rough and rocky, though no very pronounced hills exist. The valley of the Magpie is for the most part low and drift-covered, often with a sand-plain, while away from the river both to east and west low ridges of hills are divided by deep valleys. The country is completely bereft of timber, having been burnt some four or five years ago. Owing to this fact the exposures of rock are exceedingly good, and the solid rock not being much drift-covered, I had an excellent chance to study the region, and was enabled to elucidate many of the problems which had troubled me in other parts of the district.

The rocks of the area are the green schists so typical of the Michipicoten district. They consist of massive chloritic schists, seriticized and rusty quartz-porphyry schists, nacreous felsitic schists, which included sheets of granite and porphyry, and a peculiar lensoidly banded quartz porphyry schist, probably an autoclast, but often bearing a singular resemblance to a conglomerate. In the quartz porphyry schists, and sometimes in the massive chloritic schists, are the lenses of the Helen formation. All these rocks are invaded by numerous dikes and bosses of dolerite and diabase, and the region was evidently one of former volcanic activity. None of the lenses of iron formation are of any economic importance, and most of them are too small to be even discussed, consisting only of stringers a few inches wide and dying out within a few feet.

Band A, lying about a quarter of a mile south of Eccles creek, consists of a series of small broken lenses, running in an interrupted belt for some 800 yards. The lenses are mostly about three feet wide, and are of blackish and whitish crystalline chert, always intermixed with green schists. At half-way along the broken band (some 200 yards east of the boundary line between townships 28 and 29, range 26) the separated lenses collect to form a decided band of blackish and whitish chert with, in some

places, pyritous chert, and with a great deal of green schist. The schist and iron formation together are at least thirty yards wide, but the total width of all the lenses of iron formation within the schist does not exceed fifteen yards. Beyond this point the chert lenses soon narrow and die out in "tails" or appear as brecciated fragments of black and white chert or banded jasper in a matrix of soft green schist.

Band B is even narrower than the last, and is practically connected with it—the lenses arbitrarily specified as forming one band practically passing into and giving place to the lenses of the other. Like the last it consists of much impoverished magnetic black chert.

Band C lies nearer the northwest shore of Eccles lake. It consists of a number of broken lenses of banded jasper occurring in quartz-porphyry schists for some thirty yards across the strike, and is very much intermixed with schist. The lenses are traceable for some 190 yards in the direction of the strike, which is north 70° west, but in this distance the lenses often die out and only brecciated fragments are visible in the green schists. Again they reappear as tails to continue some sixty or seventy feet, then to die out again or give place to other lenses a few feet to the south or north. The widest lens was observed to have a maximum width of eight feet, and the total width of all the lenses at this point was scarcely twice that width.

Band D, which occurs some 150 yards south of the last, is of much the same general character. It has a strike of north 80° west, and dips vertically. Like the last, the iron-bearing rock is made up almost entirely of banded jasper, and in places the magnetite constituent of this rock predominates, and small seams of rather impoverished crystalline black magnetite and red hematite are found. The band was traced with several gaps, for over a quarter of a mile. It is widest some fifty yards from the lake shore, where it has a width of about eighteen yards and consists of blue-black impoverished magnetic jasper interstratified with red crystalline chert. Beyond this point the bands die out, but re-appear prominently at 110 yards and again at 300 yards.

It is evident that the scattered and disconnected lenses of iron formation, observed on the Eccles lake claims, are the remnants of former much larger bands which have been almost entirely removed by erosion, leaving only narrow shallow troughs to mark what were probably minor synclines in a larger synclinorium before sub-aereal erosion had proceeded so far as it has at present.

SPECIAL AREAS OF THE WESTERN RANGE

Near Mouth of Julia River

Outcropping prominently on the Lake Superior shore about three and a half miles southeast of the Pucaswa river, on the prominent rocky point beyond the mouth of the Julia river are ten narrow parallel bands of Helen formation. They differ so materially from each other in lithological characteristics that it will be well to describe each one separately, beginning at the most westerly, and numbering towards the east.

1. Band number 1, of rusty even-banded chert has a thickness of four feet. It is underlain by soft green schist and overlain by diabase, which appears sheet-like but which may be a dike cutting across the dip but parallel with the strike. Northwesterly from the dike along the shore, squeezed porphyrites are cut by numerous diabase dikes.

2. Some seventy feet southeast of band number 1 occurs the second band. It has a maximum thickness of 5 feet 7 inches, and strikes north 40° east and dips at 34° in a northwesterly direction. It is traceable for about 125 feet inland from the shore, and is then lost beneath drift covering. The overlying green schist looks agglomeratic, but is probably an old lava. The iron formation consists chiefly of jaspyllite, with bands of bright crimson jasper and sparkling specular hematite. Sometimes it is

slaty and pyritous. A narrow sheet of diabase four inches thick is interstratified. The jaspyllites are often highly ferruginous. A sample taken for analysis gave the following result:

	Fe.	S.	P.
No. 18..	46.41	.06	.092

3. Band 3 lies some twenty feet southeast of number 2. It dips at an angle of 24°, has a thickness of three feet nine inches, and consists chiefly of dark grayish chert. The beds show many faults, of small throw, the planes of which are cemented by calcite. Above the bed lies a schist of agglomeratic appearance.

4. Sixty-five feet southeast of the third band is the fourth band—a lens of chert two feet thick. It is underlain by evenly banded schist and overlain by a schist which looks agglomeratic. The band is traversed by a dike of diabase six feet wide.

5. Band 5, twelve feet southeast of number 4, is ten feet thick and consists of mixed impure jaspyllites and slates. It is underlain by a schist which is apparently an altered amygdaloid.

6. About 125 feet from the last band is the sixth band, only three feet thick and much mixed with phyllite.

7. At 25 feet southeast of number 6 lenses of jasper often very ferruginous, occur with ferruginous phyllites, the band in all being four feet thick and underlain by epidotic and nacreous felsitic schists.

8. Twenty-five feet beyond the last is the eighth band, which is a narrow lens of pyritous banded chert eighteen inches thick.

9. One hundred and twenty-five feet southeast of number 8 is the ninth band, three feet thick and consisting of chert, phyllite, etc.

10. The last band lies twenty-five paces beyond the ninth. The band consists from the bottom up of one foot of banded chert, two feet of soft chloritic schist, then four feet of banded, often highly ferruginous cherts and phyllites. The whole band is underlain by chloritic schists with narrow sheets of whitish felsite and overlain by chloritic schists.

All the bands of iron formation dip at angles less than 45° to the northwestward. The structure is apparently monoclinal, and there is no evidence of reduplication by faulting or folding It will be seen that in a thickness of about 293 feet of rock allowing an average dip of 35° for the horizontal width of 494 feet of schist, about 42 feet consist of sedimentary rocks of the iron formation, and the rest are apparently wholly schists of igneous origin, or for the most part of igneous origin. These bands lying near the mouth of the Julia do not seem to be of much economic value, unless the content in iron increases downward as is possible, but they are interesting as representing the type of all the western range proper—that is, of exhibiting a number of parallel beds of iron formation interstratified with schists and having what seems to be monoclinal structure. See sketch, page 336.

Laird's Claim

About three and a half miles north 20° east of the bands near the mouth of the Julia river is Laird's claim, on which occur several bands of iron formation exposed, and probably others beneath the drift, which though not outcropping are indicated by a strong magnetic attraction in crossing the strike of the beds. In going north the most southern band is the first prominent outcrop of solid rock which appears above the sand-plain stretching north from Julia river. It rises as a low cliff about nine feet high. The band of iron formation is about thirteen feet thick at the thickest point and consists of magnetic phyllites and highly magnetic banded chert, composed of impure magnetite, with bands of grayish black chert. For the most part it is almost sufficiently ferruginous to be called a lean iron ore. An analyses of a representative specimen gave the following result:

	Fe.	S.	P.
No. 19..	36.24	Traces.	.072

Overlying the iron formation is a schistose porphyrite, while beneath it is a soft chloritic schist. The band is continuous for about a quarter of a mile, and lenses out in schist to east and west. The formation has a gentle northern dip of about 16° or 18°.

North from this band lenses of magnetic chert appear in the schist for over a quarter of a mile. None of these are, however, of any prominence save the most northerly. This band is about four feet thick and dips to the northward at about 20°. It is not nearly so ferruginous as the southern band described, and consists of somewhat crumpled banded chert, under and overlain by grayish chloritic schist.

Bands North of Julia River

Stretching eastward from Laird's claim is an iron-bearing horizon over a quarter of a mile in width. This iron-bearing horizon consists by no means entirely of rocks of the iron formation, but within it occur frequent lenses and definite bands of generally very magnetic chert which are visible perhaps for a few yards only or perhaps for nearly one hundred yards, and in general the whole is very much drift-covered. Very detailed investigations will be necessary in this locality before the value of these scattered lenses of magnetic chert or, often more correctly, impure cherty magnetite, can be ascertained; but from the brief survey that we were able to give it, it would seem to be a horizon well worth while prospecting. I would suggest the carrying out of very careful magnetic work, and where that work warranted it, stripping, if this were as all feasible, otherwise the sinking of test-pits or small prospecting shafts.

The most prominent of these bands occurs a few hundred yards north of the Julia river, and about four and a half miles north of the Lake Superior shore, north from a point opposite the first considerable island southeast of the mouth of the Pucaswa river. The lense consists of bluish-black cherty magnetite, with which is interbanded some whitish chert and banded grayish chert. In places it is overlain by a magnetic phyllite, and again by a highly schistose porphyrite. The band dips in a northeasterly direction at an angle of about 33°, and strikes north 65° west. The thickness of the bed is rather uncertain, but it is probably twenty-four feet and may be more. For the most part the bed is highly ferruginous. The following analysis is that of a specimen of impure magnetite chert but there are other specimens containing a much higher content in iron:

	Fe.	S.	P.
No. 20..	38.37	.06	1.8

The bed outcrops for about fifty yards to the westward from the highest point of the cliff in which it appears, and is also visible at intervals for 150 yards in the opposite direction.

David Katossin's Claims

David Katossin's claims lie north of David's lakes, and are staked on bands of iron formation which occur in chloritic schists for nearly a quarter of a mile across the strike, and extend brokenly for over a mile in the opposite direction. The widest band which is also the most southerly, has at its widest point a surface width of 115 feet. It has a general strike of N. 80° W., and dips at 45° northward. On the north side of this band the iron formation consists of interbanded bluish impure magnetite and grayish chert. In the middle it is rusty and contains considerably sugary chert, while on the south side it is a somewhat magnetic chert. An analysis made of a rich specimen from this southern band gave the following result:

	Fe.	S.	P.
No. 21..	43.58	.10	.076

All the lenses and bands of iron formation on David Katossin's claims seem to be of very uncertain width and length, and in fact this is a characteristic of the whole western range. The bands may have a fair width for a few yards and then perhaps suddenly narrow and die out, giving place to another short lens or band

north or south of the last, which in its turn will extend some distance, and finally give place to another. The structure of the bands is apparently a series of monoclinal folds. The strike varies from N. 80° W. towards the west of the claims to N. 50° E. towards the east where cut off by granite near the Pucaswa river. As a rule the rocks consist of evenly banded magnetic cherts, but sometimes the cherts are impoverished, contain very little iron, and are crumpled or even brecciated. Like all parts of the western range, the iron formation on the David Katossin claims is much drift covered and in addition it is traversed by wide dikes and bosses of diabase and gabbro.

North of Maple Lake

Stretching from the edge of the granite on the west and extending along the northern shore of Maple lake eastward beyond Lost lake to Cameron lake, is an iron-bearing horizon in which only occasional lenses of banded magnetic chert or very cherty magnetite outcrop above the generally drift-covered surface. North from a point near the west end of Maple lake a band of magnetic and quartzitic chert appears which is at least thirty-five feet wide. It stands vertically and strikes east. This lens can be traced brokenly as far as the creek which flows from Maple lake northward to a small pond. Along this creek a good section was exposed, and may here be given in detail, measuring from the shore of Maple lake.

570 ft.—574 ft. Lens of banded black and grayish chert, interbanded with soft grayish phyllite and narrow sheets of granite.
574 " —665 " Soft green schist.
665 " —670 " Sheet of granite.
670 " —883 " Probably all schist.
883 " —890 " Lens of banded magnetic chert.
890 " —927 " Schist.
927 " —934 " Lenses of rusty sugary chert.
934 " —992 " Probably all green schist.
992 " and northward, granite.

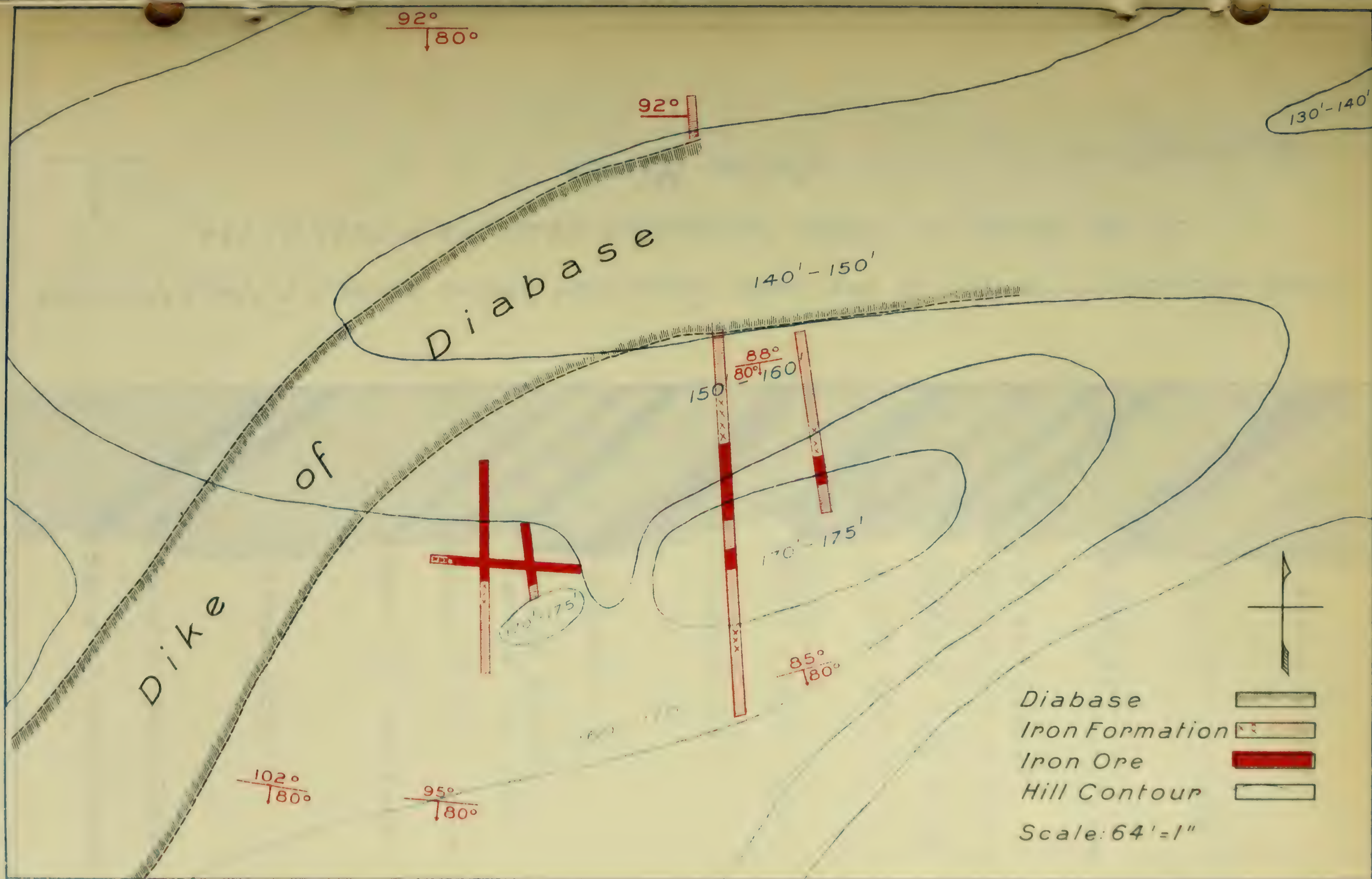
A representative specimen of iron formation from north of Maple lake analyzed as follows:

	Fe.	S.	P.
No. 22..	29.17	.51	.076

North of Lost and Cameron Lakes

East from Maple lake only isolated outcrops of magnetic chert appear, but it is evident from these few scattered exposures that the iron-bearing horizon is continuous, and that iron-bearing rocks are interstratified with schists all the way. On the hills rather more than a quarter of a mile north of Lost lake three more or less definite bands occur within a width of about 110 yards, and are continuous to the top of a high hill just west of Floating Heart creek. The widest band is about 25 yards across, and the others not much narrower. As the dip is vertical, the width on the horizontal corresponds with the thickness. The iron formation consists in the main of very evenly banded and rusty chert not very ferruginous. The strike is about N. 70° E.

West of Cameron lake the iron-bearing horizon is very wide. Lenses appear on the portage from Floating Heart creek into the north end of the lake, and again on the portage from the south end of the lake into the creek again, or more than half a mile wide. Most of the iron formation, however, is associated in a belt which starts at the base of the prominent hill about half way down the west shore of the lake, and is continuous west to the creek—or a little over half a mile in length. This belt is about 150 yards wide and about half of the width consists of iron formation, comprising banded magnetic cherts, rusty saccharoidal cherts, whitish opalescent cherts, and non-magnetic banded cherts. With these iron-bearing rocks are associated crenulated and contorted chloritic schists, which often resemble phyllites and soft whitish felsitic schists. The dip of the beds is about vertical, and the strike varies from N. 62° W. to about east and west.



Sketch Showing Stripping on Iron Ore Deposit at Scott's Prospect.

Near Fall Creek

A great many narrow lenses of iron formation occur in the green schists near the shore of Lake Superior west of Fall creek. Only a few of these are sufficiently long and wide to deserve mention. One occurs about two and three-quarters miles north 20° west of the mouth of Fall creek. It is about fifteen yards wide and is traceable for upwards of a quarter of a mile along the edge of a high cliff rising above Fall creek. It consists of very evenly banded grayish and black chert. Another lense lies in the schists some two miles northwest of the mouth of Fall creek. It consists of weathered jaspyllite, is where widest about two feet wide, and is traceable for a little over one hundred yards. Two narrow bands of iron formation in green schists may be seen on the shore of a small bay just west of Fall creek. The western band which is about three feet thick, consists of impure reddish chert mixed with schist, and the eastern band which is three to four feet thick, is composed of a highly ferruginous jaspyllite. The bands are twenty-five feet apart on the horizontal, and between them lie rusty chloritic and sericitic schists. Both bands dip to the eastward at about 45° and strike N. 5° E. Beneath the western band lie rusty sericitic schists, and above the eastern band rusty chloritic schists.

Edey Claim

From the area just described, belonging to the western Michipicoten range proper, the iron formation on the Edey claim differs very materially. The band has a length of about 275 yards and a maximum width of about 50 yards. A narrow band appears parallel with the main to the south for a few yards. The rocks are but slightly magnetic, and consist for the most part of highly ferruginous but non-magnetic banded cherts and rusty sugary cherts. The structure is very complicated. The band represents the base of an intensely corrugated syncline, very much faulted, the faulting taking place chiefly parallel with the axis of the minor longitudinal synclinal folds which make up the main synclinal. The trend of the band is about N. 70° E., and the dip of the beds usually to the northward at 50° to 70° The pitch in the short length of the bands changes in its direction several times, and is often at as high an angle as 45°. Soft chloritic schists underlie the Helen rocks, and owing to the enormous longitudinal folding and transverse folding which the rocks have suffered, the schists are brought to the surface and appear to interstratify with the Helen rocks and even replace them entirely along the strike at the summits of the transverse anticlinal folds. The band is not of much economic importance, since the amount of iron formation present is probably too small to have ever produced a large ore body.

Lorne Prospect

Some ten miles north 20° east of the mouth of the Pucaswa river, in a small area of hornblendic and micaceous schists, inter-sheeted with and also cut by gneissoid granites, occurs the Lorne prospect. The deposit, so far as the writer knows, is unique in the Michipicoten area, and consists of a highly mineralized zone in the schists. The metallic minerals present comprise chiefly magnetite, pyrite, chalcopyrite and pyrrhotite. In a somewhat rough way the deposit may be said to have a length of about 145 yards and a breadth of a least 48 y rds. These dimensions do not mark the limits of actual mineralization, since the hornblende schists to the eastward and westward give a strong magnetic attraction and even contain lenses of magnetite.

The surface of the deposit consists in the main of a rusty bog-iron ore of variable thickness, but never exceeding a few inches. Within the limits of the deposit occur narrow streaks of relatively rich material within areas of schist of slight mineralization or none at all. The schists vary in strike from N. 55° E. to N. 75° E., and dip at a high angle northward. Narrow sheets and dikes of granite, which is often porphyritic or pegmatitic, occur in and traverse the deposit, and a dike of diabase which runs abcut N. 20° W. cuts across the beds near the western end of the hill which represents

the deposit topographically. The exact limitations of the area of hornblende schist in which the deposit is found, were not ascertained; but it certainly is not wide, and as porphyritic granite outcrops on the shore of McDougall lake to the northeast of the deposit and at a short distance southward along the trail leading southwest to Camp lake. It is probably but a narrow band of Huronian schists—an inlier enclosed by the later granite, and is but a large example of many of the smaller inclusions contained in the post-Huronian acid eruptives. The connection supposed to exist between this small area of schists, and the arm of Huronian rocks stretching westward from Iron lake, has already been mentioned.

Magnetite is by far the commonest metallic mineral, but the sulphides are sometimes quite common. The limonite or rusty "iron hat" is probably often merely a rusty schist. As an ore of iron, surface specimens are too low in iron and often too high in sulphur. Analyses were made of representative specimens taken from various parts of the deposit. Number 22 shows a schist containing comparatively little magnetite from near east end of hill. Number 23, impure magnetite from west end of hill. Number 24, impure magnetite from south side of hill, near the main test pit sunk by prospectors recently working on the deposit. Number 25, the rusty limonite coating from the south side of the hill.

	Fe.	S.	P.
No. 22	25.72	.07	—
No. 23	40.92	3.20	.014
No. 24	40.17	9.39	.024
No. 25	53.75	.34	.03

In general the last three analyses may be considered slightly higher than the average for the whole hill, since the south side is apparently much richer than the north side.

The origin of this peculiar deposit is uncertain. It was probably originally a bed of ferruginous chert in chloritic schists, or interstratified beds of cherty iron carbonates varying in their content in lime, magnesia and ferrous oxide. By the metamorphism of these beds, due to the heat produced by the immense intrusions of granite, the chloritic schists or cherty carbonates high in lime or magnesia, were converted into hornblendic schists, while the ferruginous cherts or cherty carbonates high in ferric oxide were changed into schists rich in magnetite. The other metallic minerals may also have been products of metamorphism. However, this may not have been the origin, the magnetic schists may have originally been ferruginous slates, or some of the metallic minerals may have been of secondary introduction, being brought in at the time of the granite intrusion. Beneath the microscope the hornblende schists have a somewhat igneous appearance due to the presence of the mineral plagioclase, but this mineral is entirely of secondary origin, and hornblende schists undoubtedly produced by metamorphism of sedimentary rocks are certainly found in Michipicoten as seen north of Narrow lake and lake Charlotte.

A considerable quantity of low grade impure magnetite certainly exists at the Lorne prospect, and possibly further prospecting work, of which very little has yet been done, may prove the presence of richer material. If the schists are a much compressed series enclosed in a basin of eruptive granite, it would seem natural to expect an enriched deposit towards the base of this basin resting on the enclosing granite. The presence of this enriched deposit may be discovered when stripping or test-pitting has been carried out in the low ground around the base of the hill near the narrow sheets of granite, or may only be located by small prospecting shafts or diagonal drill holes.

Resume

It will be seen from a perusal of this short disquisition on the iron formation that by far the greatest part of the once extensive Helen sediments have disappeared. Doubtless enormous quantities of disintegrated ores were carried away by the strong

glacial corrasion which has laid bare the rocks in every part of the Michipicoten district, and these ores have by no means been appreciably replaced by concentration since glacial times. On the other hand glacial denudation has been most unequal in different parts of the district, doubtless more or less influenced by pre-glacial topography; and whereas in some parts of the district the entire formation, both disintegrated and non-disintegrated, has been removed, in other parts a considerable portion of the latter still remains, and it is to these parts attention ought to be drawn.

In the northern range the beds are everywhere folded into intensely compressed folds, and concentration of the ores has been found to take place at or towards the bottom of the troughs. Only in so far as the lower part of the trough was in the zone of corrasion would the concentrated ore be swept away. Therefore in the still existing deep troughs, since by far the greatest part of ore concentration took place prior to the period of glacial denudation, when the Helen formation was still extensive, it is reasonable to expect that ore-bodies of considerable magnitude may be found. Deep troughs of this nature may be said to exist at Iron lake, at the Frances mine, at Brotherton hill, and at the Leach lake bands, especially near Scott's prospect.

In the western range structural conditions are very different from the northern range. The beds are broadly folded, but not nearly so intensely corrugated as on the northern range. For this reason we get them appearing in monoclines, or what appear to be monoclines, though the angle of dip of the beds varies from 12° to vertical. Gentle cross folds may traverse the monoclines, producing shallow troughs in which ore enrichment might be expected, or dikes or bosses of eruptive rocks, undoubtedly present, may have in some cases given the necessary basin. It is very possible that faulting, particularly faulting parallel with the dip and strike, may be very common in both the northern and western ranges, and this may in many cases give departures from the general rule of ore deposition and ore deposits.

In general, the iron formation at the surface in the western range is much more highly ferruginous than on the northern range. This is supposed to be due not so much to any original difference between the beds in the two ranges, but to the fact that, owing to the more broken up, brecciated, jointed and faulted condition of the iron formation in the northern range, concentration of the iron ores at the bottoms of troughs has gone on to a much greater degree there than on the western range. On the whole, this may be considered an unfavorable sign for the western range.

It may be suggested that the beds of iron formation on the western range are not sufficiently wide to have ever produced a large ore body. At first sight this would seem to be the case all over the range, and probably for many localities this objection is a good one. However, it must be remembered that in the case of the western range we speak usually of the thickness of the beds and not of the width of the bands, as in the case of the northern range. In the northern range, owing to the intense plication, the width of the bands represents the thickness of the individual beds, many times multiplied. For example, in the case of the Iron lake area we have no means of telling how thick the original bed of iron formation was, but we do know the width of the band—often 600 feet or more. Now that width probably represents the thickness of the original bed at least twenty-five times repeated, so close has been the folding. It may be supposed that the lateral extent of the original beds of iron formation was not less on the western range than on the northern range, proportionate of course in both cases to the thickness. For this reason we might naturally expect as large an ore-body to be derived from a fairly thick bed of wide extent, along the strike and down the dip, as from a wide band of considerable depth, within the limitations that the amount of iron formation was approximately the same in both cases, that the two iron formations were equally rich in iron, and that the means by which concentration took place were equally good for both. Among localities of fairly favorable appearance on the western range may be mentioned Laird's claims, Julia river bands, David Katossin claims and Lost lake.

In general, the exposures of the Helen rocks are not nearly so good on the western range as on the northern, and the structure in many cases could not be so well ascertained in the former as in the latter. The great folding on the Edey claim, as compared with the comparatively gentle folding on the Julia river bands and elsewhere, may be explained by the fact that the Edey claim is close to the centre of greatest plication (close to the edge of the granite), whereas the more gentle folded areas are more remotely removed. For a similar reason, the beds of iron formation from Maple lake to Lost lake stand at higher angles than those of other localities.

THE UPPER HURONIAN

Doré Formation

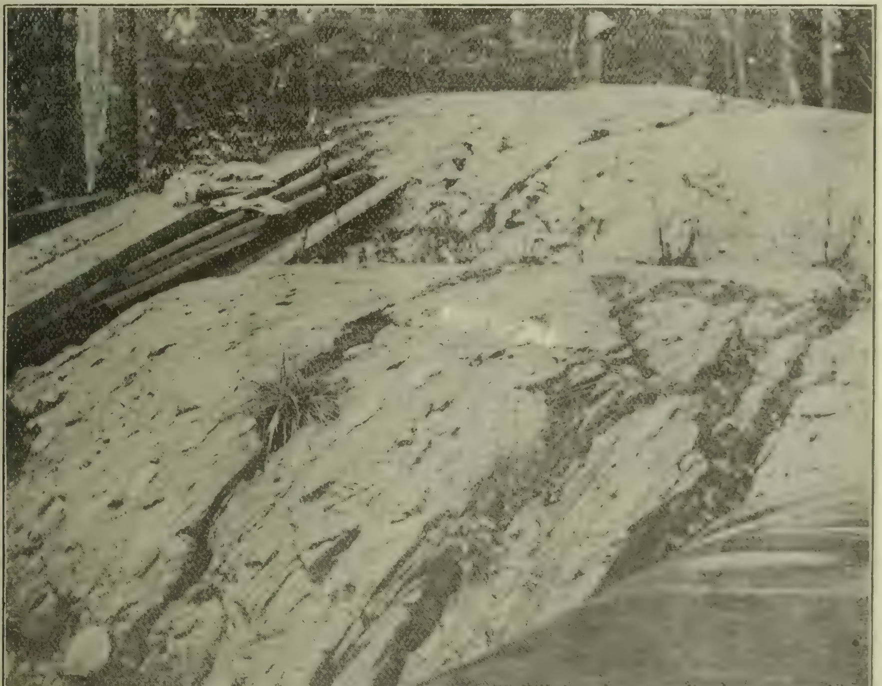
In a general way the Doré Formation is spoken of as the Doré conglomerate, but there are Doré agglomerates, Doré tuffs, and Doré slates, contemporaneous with the conglomerate, though the latter composed by far the greatest part of the formation.

PETROGRAPHY OF THE CONGLOMERATE

The Doré conglomerate is the most extensive true waterlaid sediment in the region. It is an exceedingly mashed rock consisting of a rather fine-grained matrix in which are embedded fragments of every size from those truly microscopical up to others two feet in diameter. All the pebbles are elongated, some nearly oval-shaped, others drawn into long narrow ribbons, or again completely granulated, their character lost and even under the microscope scarcely distinguishable from the matrix proper. Megascopically, the matrix often resembles a soft grayish chloritic schist, very much decomposed, occasionally rusty, and where pebbles are absent in some places indistinguishable from a schist formed from an igneous rock. Beneath the microscope the prevailing clastic material of the matrix consists of quartz and chlorite, the former in small rounded grains, the latter in irregular frayed flakes. With these primary minerals occur a great deal of secondary infiltrated carbonate, often more or less oxidized with the formation of hydrous iron oxide; much chalcedonic silica, much sericite, fairly coarsely crystalline quartz; foils of muscovite and idiomorphic crystals of pyrite. This latter secondary material occurs as re-cementing substance chiefly with the crushed and granulated matter formed from the contusion of the smaller pebbles. These crushed pebbles, generally derived from rocks of igneous origin, mix with the altered material of the original matrix strained plates of various decomposed feldspars, and more or less worn grains of much altered ferro-magnesian minerals. Thus the matrix is given in many places the appearance of a typical igneous rock, and with all the pebbles comminuted, might easily be mistaken for a rock of that origin; but as a rule the real nature of the rock is apparent in the field and the extreme phase of dynamic metamorphism is rarely seen even beneath the microscope. Even where the matrix includes no additions derived from the pulverization of the pebbles, it contains comparatively little original material and consists chiefly or in great part of secondary minerals. Thus its former character is entirely changed, and little clue as to its primary condition is gained by its microscopic study. Probably it was originally a rather sandy, argillaceous material.

In some parts of the areas, as southwest of Black Trout lake, near the Magpie river, the matrix of the conglomerate very strongly resembles a rusty sericite schist —and since it contains many rounded fragments of bluish quartz, it has the general appearance of being an altered quartz porphyry. In addition to quartz grains the matrix contains zircon, magnetite, and altered feldspars which are probably primary fragments, and biotite and chlorite which may or may not be secondary.

Like the matrix, the pebbles are much decomposed. The following rocks are represented: chert, quartz, quartz-porphyry, massive basic igneous rocks, fine-grained schistose rocks of various colors, porphyrites, black slate, and finally in places granite. It was seen that the proportion of these rocks to each other varied greatly from point to point. In some places, particularly adjoining the iron formation, cherty rocks predominate, or are at least of great consequence, while farther away they are entirely wanting. Pebbles of a light colored soft rock, with blebs of glassy quartz occurring in a sericitic ground-mass—probably an altered quartz-porphyry—and others of a grayish much altered and generally porphyritic granite, are perhaps in general the most common. The pebbles of the former sort are probably derived from the mashed quartz-porphyries which form such an important part of the volcanic rocks of the Lower Huronian, but the derivation of pebbles of the latter description is not so easily found, and to my knowledge there is at present no similar granitic rock of age earlier than the conglomerate existing in Michipicoten from which these very characteristic



Doré conglomerate, near Michipicoten Harbor.

pebbles could have been derived. It is very likely that pebbles of the softer schists and less silicious rocks were originally much more common than they are at present, and often are still seen, but the intense shearing which the formation has undergone has as a rule so broken them up that they are no longer visible or are indistinguishable from the matrix. In some places the pebbles in the conglomerate are so closely packed as practically to exclude the matrix, again the matrix may very much predominate and pebbles be visible only at wide intervals. The granitic pebbles do not generally resemble the post-Huronian granites. They are much more porphyritic than is usual with the granites of that age.

The quartz pebbles result evidently from the disintegration of the small stringers and veinlets of this mineral which are of common occurrence in the Michipicoten schists, but not from the larger veins which are probably of later age than the conglomerate. The pebbles derived from the Helen iron formation included in the Doré

conglomerate are mostly of the coarsely granular chert or "sandstone jasper" type, though a few show distinct banding and are obtained from impoverished banded jaspers. The occurrence of these pebbles of banded jaspers seems to me a further proof that not all of these rocks composed of interbanded layers of iron oxide and of chert, have resulted from the metasomatic alteration of cherty carbonates, since these alterations could not have taken place beneath water and the disintegration of the Helen formation started as soon as it was elevated above water.

The pebbles of the massive basic igneous rocks are so much changed that their original character can barely be guessed, but it is presumed that they are derived from the coarse-grained greenstones, often schistose, which are so common near the base of the Lower Huronian series. Pebbles of the more easily decomposed schists are scarcely visible in the conglomerate, save as long drawn out ribbon-like lenses and these, completely chloritized, so much resemble the matrix as to be indistinguishable from it, save occasionally by the difference in color in the hand specimen. A few pebbles of black slate or phyllite were observed in several places, and the fact of their occurrence in the conglomerate is of interest in showing that at least some of the rocks of this character belong not to the Upper Huronian but to the Lower.

PETROGRAPHY OF THE AGGLOMERATE

At some few places associated with the conglomerate and grading imperceptibly into it, is a soft greenish schist containing numerous rounded, lensoid or ribboned pebbles, or more correctly what at first sight appear to be pebbles, but which on closer examination are seen to be all lithologically similar, and are apparently bombs, lapilli, or other volcanic ejectamenta. The matrix of this agglomerate very closely resembles megascopically that of the Doré conglomerate, but microscopically the igneous origin of the former is shown. In the field the pseudo-pebbles weather lighter than the matrix, giving it a peculiar blotched appearance which is very distinctive. Typical exposures of this pyroclastic rock are visible on the portage from Pitch-pine lake to the Dog river and on the portage from the Frances mine to the Dog river.

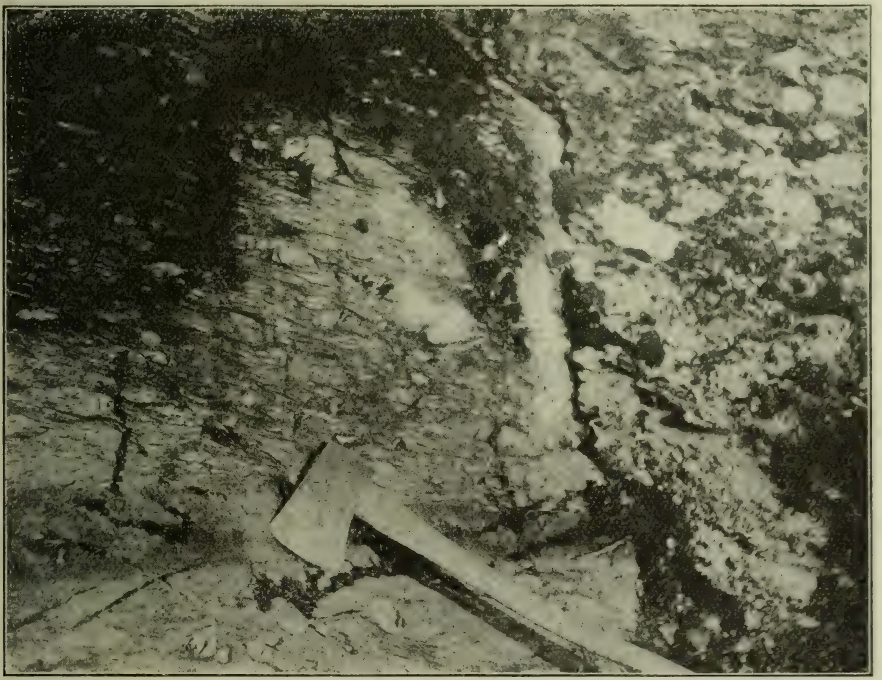
In both these instances the agglomerate is directly interstratified with the conglomerate. Where, however, agglomerates occur which are not directly associated with conglomerates, then it is not so easy to consider them of Doré age. Agglomeratic rocks which are probably Lower Huronian in age are common, and these can hardly be distinguished from those of Upper Huronian age. Agglomerates appear on the shores of the sixth lake north of Dog River harbor, on the route to lake Michi-Biju, which are of uncertain age. The ground-mass is a light greenish, chloritic, felsitic schist, in which are embedded the felsite and quartz fragments, elongated parallel to the schistosity. Similar rocks are found on the Lake Superior shore, about two miles west of the Dog river; on Catfish creek, some three miles north of Catfish lake; at the northeast corner of Catfish lake, and at many other points. Without direct association with Doré conglomerate there is no reason why these rocks can be classed with them, and for the present they are considered Lower Huronian.

A somewhat rare phase of the Doré agglomerate is one in which the larger fragments disappear. The agglomerate may then be considered a tuff. From the occurrence of the Doré agglomerate it is evident that volcanic activity continued during Upper Huronian times, laying down volcanic beds in connection with the waterlaid sediments of the conglomerate.

At a great many places in the Doré formation extensive and unequal denudation has brought to the surface the underlying green schists, some of which, as already described, are altered tuffs. These may resemble the agglomerates and fine-grained tuffs contemporaneous with the Doré conglomerates, and may not easily be separable from them.

PETROGRAPHY OF THE SLATE

A somewhat uncommon phase of the Doré conglomerate is one in which pebbles are entirely lacking. This is practically a slate or phyllite, closely resembling the argillaceous rocks belonging to the Lower Huronian, with which it might be erroneously classed from lithological considerations, were it not for its intimate connection with the Doré conglomerate. The long point which divides Minnesota bay from the southwestern bay of Iron lake is composed at least in part of this Upper Huronian



Doré Conglomerate, Iron lake.

phyllite, and similar rocks occur with the Doré conglomerate, just east of the mouth of the Dog river.

The Doré conglomerate must not be confused with the various pseudo-conglomerates which occur so widely and are almost indistinguishable from the water-formed rock. Several of these have been already described. They are usually autoclastic rocks, and a typical example is that resulting from the brecciation and subsequent rounding by mashing of small lenses of jasper and quartz occurring in soft quartz-porphyry schists. This phenomenon is well observed on the Eccles lake claims, where in places the sericitic schists form the matrix of false-pebbles of quartz jasper.

DISTRIBUTION OF THE FORMATION

The distribution of the Doré formation is extensive throughout northern Michipicoten. Starting near the entrance of Farwell creek into the eastern branch of the Pucaswa river on the west, it extends as a continuous belt in a direction north 70° east to the south shore of Iron lake. South of the western end of Minnesota bay the formation outcrops for slightly over a mile across the strike, and as a sand-plain borders it to the southward, this width may be somewhat increased. From Iron lake the band gradually narrows, and where it crosses the Dog river is probably under half a mile in width. An isolated outcrop of the conglomerate filled with chert pebbles,

occurs in the eastward continuation of the trough between the two bands of iron formation on the Katossin claim. This outcrop is probably one-quarter of a mile north of the main belt of the Doré formation, and indicates its former greater extension. The phyllites occurring at the Rapid of the Drowned on the Dog river and cut by a small dike of acid quartz porphyry at the southern end of the portage from Pitchpine lake to the Dog river, are probably of Doré age.

From the Dog river the formation runs east towards Paint lake. At the western end of the lake no outcrops of the formation were seen, but it reappears north of Paint lake and continues eastward to Kabenung lake, just south of and opposite Iserhoff island, where it is cut off by granite intrusives. North of Paint lake the Doré formation is nowhere continuous and unbroken, exposures of the conglomerate alternating with outcrops of sericite schists, and other earlier rocks. Evidently erosion has cut through the later rocks and exposed the underlying. An isolated appearance of a conglomeratic looking rock was seen about half a mile west of Crayfish lake, just beyond the boundary of the granite. It is doubtful whether it is to be connected with the Doré formation.

North of the Kabenung granite mass, the Doré formation reappears along the north shore of lake Charlotte. West of lake Charlotte outcrops of the conglomerate are wanting as far as the northern neck between east and west Kabenung lake, where the formation is observed to be running about southeast, and it continues in this direction as far as White Water-Lily pond. Here it turns abruptly and passes off to the north of Leach lake in a more or less easterly direction, than northeasterly. North of Water-Lily pond the width of the formation is some 700 yards, but appearing frequently with the conglomerate are outcrops of the mashed quartz-porphyry, again showing that erosion has eaten in many places through the Upper Huronian and brought the older rocks to the surface. North of Leach lake the Doré formation bends around the intruding granite boss, and passing to the north of Lonely lake crosses lake Desolation.

Eastward from lake Desolation no rocks certainly belonging with the Doré conglomerate are found, but there are rocks which may be part of that formation and which are tentatively classed with it. These rocks which consist of a fine-grained chloritic and micaceous matrix, with many "pebbles" or what appear to be pebbles of granite, felsite, and rarely quartz embedded within it, may be conglomerates; but from the fact that no definitely clastic material is discoverable beneath the microscope they cannot be definitely said to be water-formed. Moreover, the pebbles consist in the main of the same elementary minerals as the ground-mass, which gives it the general character of a volcanic breccia or agglomerate. However, the fragments are frequently rounded and resemble pebbles or cobbles worn in or by water. Again, on the other hand, they are sometimes drawn into long lenses, but certainly true conglomerates contain pebbles drawn into similar lenses. Another point which seems to suggest their not being true conglomerates is the absence of pebbles of all rocks, not of the same character as the matrix, save quartz. "Fragments" of quartz are comparatively rare, and those found may not in reality be true fragments, but may be material introduced by solutions after the laying down of the rocks, since they are generally long and lensoid, like tiny veinlets. In the field, however, these rocks look distinctly like conglomerates and are at present considered as such. They outcrop at about two and a half miles north of lake Pasho-Scoota, southeast of the lake on the north boundary of township 29, range 26, near Evans creek, and on the eastern side of the Magpie on Cradle Creek, less than a mile above its mouth. At the last-named place the fragments of granite and granitic rocks are particularly common in the matrix. One thing that may be remarked in connection with these doubtful conglomerates is that they always occur close to the edge of the granite.

Bands of conglomerates appear on the southern boundary line of township 28, range 26, at and below McKinnon's bridge, at the Steep Hill portage on the Magpie, and near Black Trout lake, and a wide area extends eastward from the mouth of the

Doré river for some six miles. The Doré river band has been described by Professor Coleman[16] and need not be mentioned here. The Doré conglomerate southwest of Black Trout lake has, as has been mentioned, a ground-mass very much resembling a quartz-porphyry schist. The pebbles consist chiefly of quartz porphyry, granite, and quartz, though narrow lenses of dark greenish material may represent drawn-out green schist pebbles. Often the rock has a distinct agglomeratic appearance, and may indeed sometimes be an agglomerate.

Gneiss-agglomerate, Cradle creek, Michipicoten.

The conglomerate which occurs just above and just below McKinnon's bridge on the Magpie river, contains pebbles much squeezed and elongated, parallel to the foliation, and varying in size from those visible with the microscope up to others six inches long. Felsite and acid porphyrites are the commonest pebbles, but several of rusty chert may also be observed. The phyllites which appear on the right bank of the river just below the conglomerate, are apparently of the Doré formation. They are for the most part almost black, but have interbanded, much narrower bands of light gray phyllite, which is sometimes somewhat coarse-grained and resembles a graywacké. The outcrop shows well the relationship existing between true bedding and cleavage. The bedding planes strike N. 34° W., whereas that of the planes of schistosity (or slaty cleavage) is N. 60° W. The true dip also is vertical, whereas the dip of the planes of schistosity is in a northeasterly direction at about 60°. The outcrop very strongly resembles that of phyllites and arkose on Reed lake already described. It has already been mentioned in describing that occurrence that the age of these rocks was uncertain, and they may in reality be Upper Huronian.

In the western Huronian area, outcrops of the Doré formation are rare. There is a characteristic exposure of Doré conglomerate with associated phyllites just east of the mouth of the Dog river. This band runs in a direction N. 40° W., and I

16 Eighth Rep. Bur. Mines, 1899, p. 132; Ninth Rep., 1900, pp. 183-4, and Eleventh Rep., 1902, pp. 155 and 162.

believe crosses the Dog river a short distance above its mouth. The most common pebbles are of granite, and next to granite those of chert. The schist pebbles are much flattened, and all pebbles are elongated parallel to the foliation. None of the pebbles are very large, those six inches long being about the longest. There is a wide outcrop of Doré conglomerate near the eastern branch of the Pucaswa river, southwest of lake Ellen. The ordinary pebbles occur and the matrix is of characteristic appearance. The width of the band is at least a mile at the widest point, but in this distance earlier rocks than the Doré conglomerate appear at the surface and indicate the removal by erosion of part of the conglomerate, and the laying bare of the underlying rock.

It is impossible to estimate the thickness of the conglomerate in northern Michipicoten, owing to its complexly folded character. It has been observed that its width south of Iron lake is at least a mile. At this point folding is particularly close, and its beds are almost all standing in vertical attitude. It is probable that the thickness is many times repeated. Secondary structures are strongly developed. Cleavage and schistosity are parallel to the axes of the isoclinal folds, and to the boundary between the Helen formation and the Doré formation. Truly ascertained bedding is seldom seen, excepting in the more slaty varieties of the conglomerate. In the conglomerate occurring just east of the Dog river, considering the dip to be uniform at 90° or vertical across the bed and presuming there is no reduplication, the width and thickness correspond at 109 + yards (68 yards conglomerate and 41 + yards phyllite).

THE POST-HURONIAN ACID ERUPTIVES

NOTE.—To accord with the new system of Archean nomenclature, and also to correspond with previous mapping of the region by Professors Coleman and Willmott, these rocks should, in part at least, be called "Laurentian".—T.W.G.

The post-Huronian acid eruptives consist of granites, felsites, syenites and quartz-porphyries. These rocks are all more or less sheared, but never as much so as are the acid schists which they intrude, and this fact is occasionally a method of distinguishing them from the older rock. As they are intrusive through the Lower Huronian schists, and the Helen formation, as well as through the Upper Huronian Doré conglomerate, they are of course younger than these formations. This relation is obtained from ample evidence seen along the contact of the granite with the various formations, and representative instances will be given later.

So far as certainly known, all the post-Huronian acid igneous rocks were eruptive rather than effusive, but some of them may have been the latter. as shown by an isolated example to the northwest of Iron lake, where a devitrified lava, probably a trachyte, with a felsitic ground-mass, shows faint evidence of flow-structure, From this single occurrence little information can be gained, but doubtless very careful study along the contact of the Huronian rocks with the post-Huronian acid eruptives would do much to elucidate this as well as many other difficult problems.

Petrography of the Eruptives

From a textural standpoint the acid eruptives are divisible into two distinct phases—the porphyritic facies, and the granitoid facies. To the former belong not only the quartz porphyries, and syenite porphyries, but the felsites which are always more or less porphyritic with feldspar phenocrysts. To the latter belong the granites and syenites.

The post-Huronian quartz-porphyry does not differ materially in macroscopical appearance from the rocks of the same species belonging to the Lower Huronian, save as a rule in that the former is less porphyritic, fresher, and somewhat less strained than the latter, but sometimes near the contact they are almost indistinguishable.

The typical quartz porphyry shows an aphanitic ground-mass dotted with various phenocrysts. Beneath the microscope the ground-mass is seen to be almost micro-felsitic in texture, and to consist of various feldspars (hardly recognizable but probably orthoclase, microcline and acid oligoclase) with biotite, hornblende, and quartz. Muscovite is a common secondary product of the feldspars, and with it is often associated some carbonate. The biotites are often chloritized. Pyrites is a common accessory. In this ground-mass are embedded the comparatively large phenocrysts of quartz, with others of orthoclase and acid oligoclase. Many of the quartzes are granulated, and those which are still intact show undulatory extinction. The feldspar phenocrysts, always strained, are surrounded by a halo of degradational minerals.

By an increase in the quantity of feldspar and in the ground-mass, and by a decrease in the number of phenocrysts, the quartz-porphyry grades into a felsite. By a decrease in the quantity of quartz both as phenocrysts and in the ground-mass, and a relative increase in the number of feldspar phenocrysts and of biotite and hornblende in the ground-mass, the type passes into a mica syenite porphyry. This is really the transitional rock between the rocks of porphyritic texture and those of granitoid texture, for though it contains numerous phenocrysts, the ground-mass is not felsitic but granitoid. In some cases the phenocrysts are so common as almost to exclude the ground-mass. They are often large and consist of oligoclase (An_{28} Ab_{72}) microcline and microperthite. Oligoclase in large automorphic plates is the most common species. It occasionally shows zonal decomposition, and is with the other feldspars much squeezed, sometimes comminuted, and often surrounded by rings of secondary minerals. The ground-mass contains the original minerals biotite, quartz, apatite, titanite, pyrite and the feldspars. Biotite is not a very common mineral, and is sometimes chloritized. Quartz is rare, but secondary chalcedony has developed from the decay of the feldspars. Apatite occurs as inclusions in the feldspars and even in pyrite. Titanite is common within all the feldspars as small irregular rhomboids and occurs independently in large granular masses. Pyrite exists in regular square and triangular forms. Calcite, muscovite and secondary microcline are alteration products of the original feldspars.

From the ground-mass of the mica-syenite porphyry the normal granite type differs only in an increase in the amount of quartz and a decrease in the amount of plagioclase, as compared with orthoclase. As a rule it is a medium to coarse grained rock containing the following original minerals—quartz, microcline, orthoclase, oligoclase, biotite, rarely hornblende with titanite and apatite. The rock is always sheared. all the minerals show strain, and zones of granulated quartz with various metamorphic minerals; muscovite, epidote, chlorite, calcite, etc., occupy the spaces between the larger but always more or less corraded individuals.

By a decrease in the quantity of ferromagnesian minerals the normal granite passes into a quartz-microcline granite, almost free from ferromagnesian minerals. By an increase in the ferromagnesian minerals, and by a decrease in the amount of quartz, the rock becomes a hornblende granite or normal syenite. The quartz microcline granites, hornblende granites, and syenites are all common rocks in the acid eruptive complex of Michipicoten.

The post-Huronian acid eruptives which enclose the areas of Huronian rocks, are of extremely irregular outline, but they are all apparently connected with the immense area of gneissic and granitic rocks which form such a prominent part of the Archean of Central Canada. However, considering the slight knowledge of the granites and gneisses lying north of Michipicoten, this may seem rather a bold statement, and it is probable that there are granites and gneisses of more than one age in this huge complex.

Distribution of the Eruptives

Beginning at the Magpie river on the east, the boundary of the acid eruptives may be traced as follows. The boundary crosses the Magpie about one mile south of the foot of the Long Rapid. It then strikes northwesterly, north of the lake on

the northern boundary of township 29, range 26. Thence it follows a somewhat westerly course to the eastern end of Kabenung lake, and beyond that body of water north of lake Charlotte to lake George. It then suddenly turns east, and crossing the Dog river near the mouth of the Crayfish, it continues an eastward course south of lake Charlotte. Thence it bends southeastward, and encloses Big island of Kabenung lake, forming the Kabenung granite boss. From Kabenung lake the boundary sends off an apophysis which cuts the Helen formation at mount Raymond. It then bends north and recrosses the Dog river at the head of the rapids, just north of Heart lake. From the Dog river its course is in a general west-southwesterly direction, as far as a point about seven and a half miles west of Ellen lake. Here the Huronian rocks seem to die out, and the granite boundary turns east, and running first in an east-northeasterly direction and then straight east, it crosses the Dog river just below the mouth of Ekinu creek. Thence it continues eastward and crosses the northern arm of Jimmy Kash lake. From Jimmy Kash lake it runs northeastward to Lac Poisson

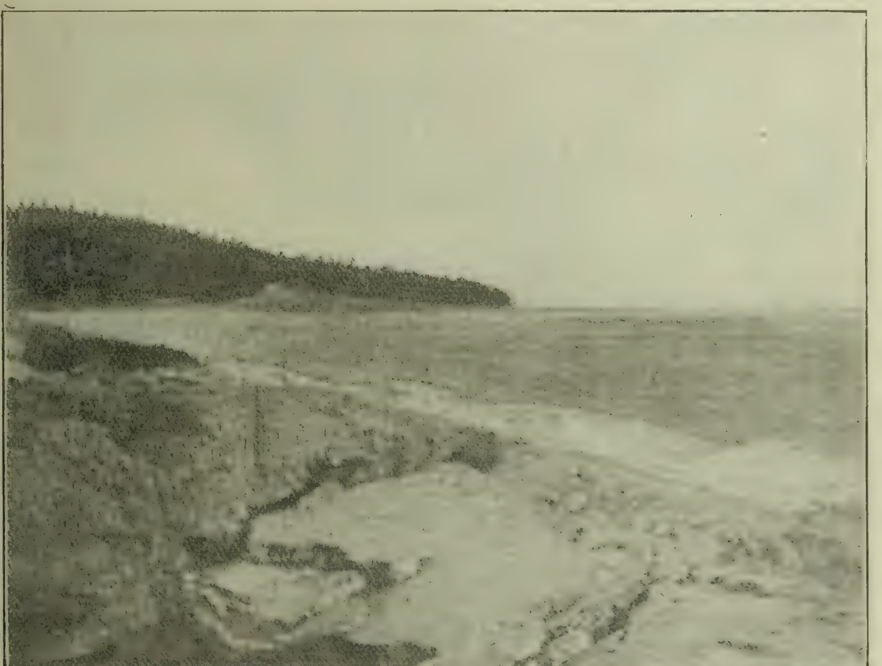
Jointed granite, Lake Superior shore, near Eagle river.

Gris and encloses Leach lake. From Leach lake it bends southerly and then southwesterly, crossing the southern boundary of township 31, range 26, near the crossing of the Doré river. Thence it bends southeast almost to Catfish lake and then turns more southerly to Black Trout lake. From the southern end of Black Trout lake it pursues a general southwesterly course, south of Doré lake, reaching the shore of Lake Superior between the mouth of the Doré and Little Bear rivers.

Occasional very small isolated outcrops of Huronian rocks are said to appear along the shore of Lake Superior westward from the mouth of Little Bear river; but no decided Huronian area is seen until a point about one mile west of Mountain Ash river is reached, and this may be said to be the boundary between the post-Huronian acid eruptives and the Huronian rocks. From here the line between the two series runs northeastward to the Dog river, which it crosses about eight miles above its mouth. It then turns southward and crossing the western bay of Duck lake, it continues the

same course for about two miles, where it bends eastward to a point about three miles north of the mouth of the Eagle river, whence its course to the Lake Superior shore is about south.

For fifteen miles west of the Eagle river granites prevail along the Lake Superior shore, then near Pilot harbor schists reappear. The boundary between the schists and the granite strikes north-northeast from this point to the eastern branch of the Pucaswa river. It then bends in a generally easterly direction to the shores of lake Michi-Biju, of Michi lake, and of Katzenbach lake. Thence it turns south follows close to the eastern margin of Katzenbach lake, and then bends west around the south of lake Michi-Biju. From the western bay of this body of water it strikes south-southwest to Floating Heart lake, whence it runs west-southwest north of Lost lake and Maple lake. West of Maple lake it bends easterly again and pursues a general east-southeasterly course for about six miles, then it turns northeasterly



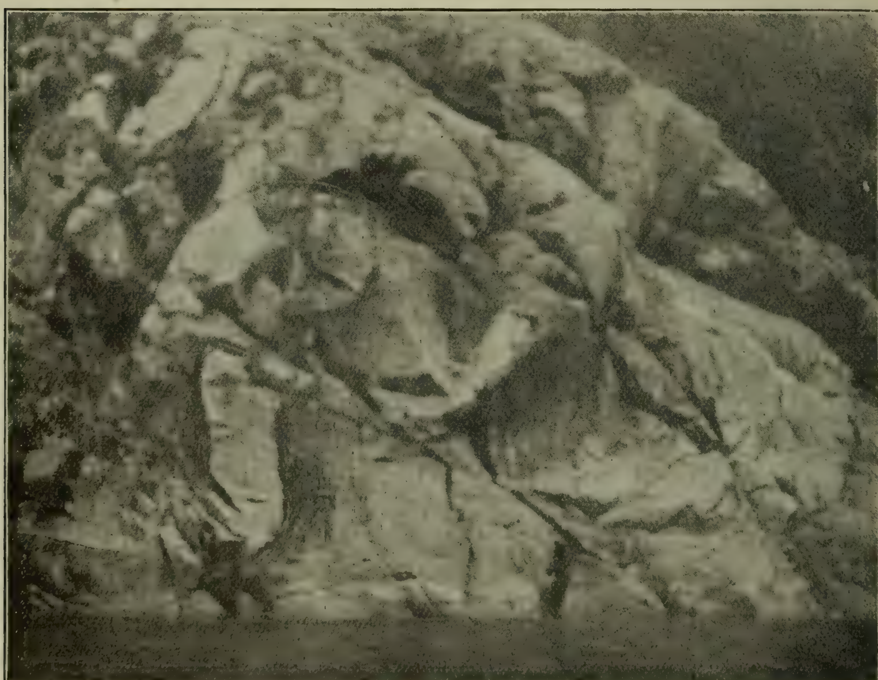
Laurento-Huronian contact, near Eagle river, Lake Superior.

for four miles, and then generally easterly for four miles as far as the crossing of the boundary of the Michipicoten Mining Division. Thence the boundary gradually circles around from east to northeast, then north, and then northwest, and finally west to Miron lake. From Miron lake it bends northwesterly as far as a point three and a half miles west of Ellen lake. From this place its course to the Lake Superior shore is about west-southwest, a distance of some miles. I have placed the boundary between the post-Huronian acid eruptives and the Huronian rocks on the point between Richardson's harbor and the mouth of the Imogen river. Previous geologists in the area have put it at Otter Head, some six and a half miles farther west. I have placed it on the point west of the Imogen because the few areas of schists which appear west of this point are small and unimportant, and are apparently merely inclusions within the predominating granite. On the other hand, no prominent areas of post-Huronian acid eruptive rocks occur eastward from this point until the large area of granite near Pilot harbor commences

Besides these large areas of granite which enclose the Huronian rocks, there are many dikes and bosses of post-Huronian acid eruptives which are found within the limits of the Huronian rocks.

Contact with the older rocks

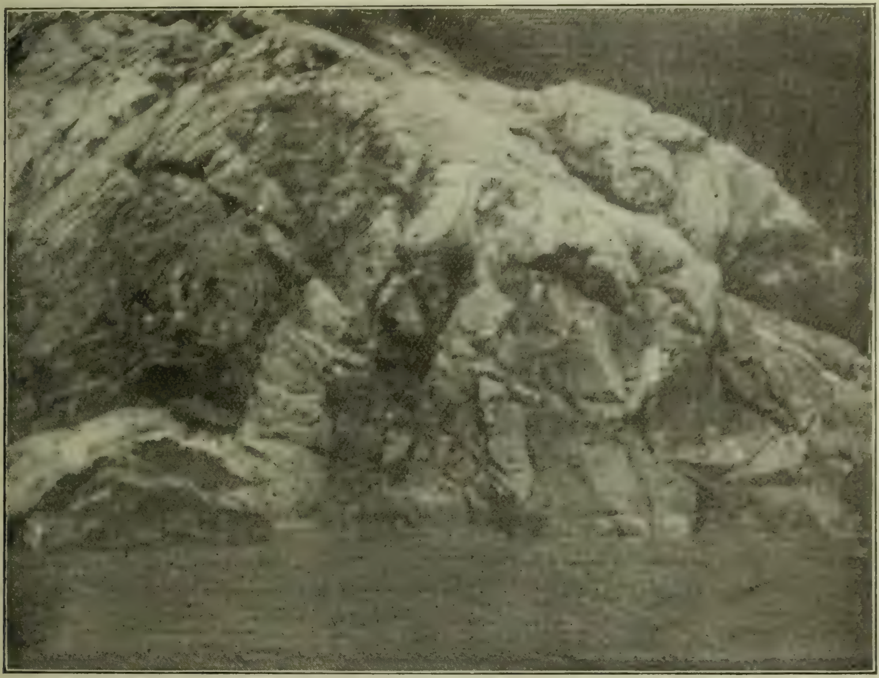
Among the post-Huronian acid eruptives there is a tendency to assume the porphyritic or felsitic phase towards the contact with the older rock, while away from the contact the coarse-grained granitoid type prevails. Furthermore, it was noticed that these porphyritic or felsitic rocks were in some places near the contact so schistose that often they closely resembled the Lower Huronian acid igneous rocks, and the boundary was in these places, in consequence, delineated with some difficulty. This highly foliated phase of the acid rocks is more common towards the edge of the main mass, or its larger offshoots than in the less prominent bosses, and often the smaller apophyses injected into lower formations are coarse-grained. It may be presumed that the latter were intruded in depth, while the former owe their porphyritic and felsitic character to intrusion not far from the cooling influence of the surface.



Anticlinal structure, shown by folded sheet of granite, near mouth of Eagle river, Lake Superior.

A very interesting contact is that seen north of lake Charlotte. This body of water is situated in the long, narrow, westwardly opening embayment of Huronian rocks bounded to the south by the Kabenung granite boss, and to the north by the main mass of post-Huronian acid eruptives. The contact here described is probably many times repeated along the edge of the Huronian areas, but at this particular point it is better shown than elsewhere because all the vegetation has been removed by a fire which swept the country around lake Charlotte. The rocks exposed along the northern shore of the lake include banded rusty cherts, hornblende schists, micaceous schists and epidote schists. The hornblende schists are for the most part banded

cherts changed by contact metamorphism, and the micaceous and epidotic schists, chloritic schists similarly altered. With them are interstratified narrow, very light colored silicious quartz-porphyry sheets. Passing northwards from the lake the sheets of quartz-porphyry and gneissic felsite increase in number in the schists, the sheets become wider, and the bands of schist narrower and more intensely metamorphosed. Numerous apophyses connect the various sheets. Still farther north the irruptive rocks prevail over the invaded, and at a little more than a quarter of a mile back from the water alone appear.



Folded sheets of granite (?) or felsite (?) near mouth of Eagle River, Lake Superior.

South of lake Charlotte and between that body of water and Nematequin lake occurs the contact of the green schists with the Kabenung granite boss, which is entirely different from the northern contact. It is abrupt, decided and closely demarcated. The granite is coarse-grained and often porphyritic, encloses numerous fragments, and sends off short apophyses into the schists.

The best visible contact of the acid eruptives with the Helen formation is that seen at mount Raymond, just west of Paint lake. Here an arm from the Kabenung granite boss cuts across the belt of Helen sediments. The alteration of the Helen sediments to various amphibole schists, of the slates to epidote schists, and the occurrence of wide veins of quartz and of deposits of very impure magnetite—all contact phenomena due to the intrusion of the huge granitic mass—have already been described. The changes in the intruding rock a gneissoid granite porphyry, are also interesting. The immediate edge of the boss is highly foliated and towards the centre it is coarse-grained and but slightly schistose. Numerous fragments both of the iron formation and of the schists which border it, are enclosed within the irrupitve toward the edge.

The eruptive relations of the post-Huronian acid igneous rocks with the Doré formation are not so well shown in the northern part of Michipicoten as in the southern part. However, on the shores of East Kabenung lake and to the south of lake Charlotte, narrow dikes of granite, apophyses from the Kabenung granite, cut the

formation. An excellent contact of the Doré formation with the post-Huronian granite occurs on the Lake Superior shore a few miles west of the Doré river, and distinctly shows the irruptive relations of the latter.

Somewhat interesting is the geological section exhibited along the Lake Superior shore from Otter Head eastward. Owing to the constant washing of the waves, the rocks are excellently exposed, and the relations existing between them well shown. At Otter Head the rocks consist of small areas of evenly banded gneiss, ordinary light reddish granite, coarse-grained pegmatite, quartz and calcite veins, and diabase. The gneiss is composed of alternating bands one-quarter of an inch and less in width of dark colored minerals, chiefly biotite, and of light colored minerals, chiefly ortholcase, oligoclase and quartz. The light colored granite, which is probably the commonest rock, is a typical post-Huronian eruptive. The pegmatite, consisting chiefly of large individuals of feldspars, quartz and biotite, was probably formed as the result of steam acting upon the hot granitic magma, either during or immediately following its intrusion. The veins are later than either granite or pegmatite, but probably they owe their origin to the circulating thermal waters which followed and were the result of the granitic intrusion. Eastward from Otter Head the inclusions of gneiss appear of finer grain, though always very evenly banded. Gradually they become more common, increase in width, become definite bands alternating with areas of granite and more closely resemble the ordinary types of schist. Sometimes the bands of schists are crossed by dikes of granite joining two sheets of this rock. Finally, at about six and a half miles east of Otter Head, the granites give place to the schists and the latter become the prevailing rock.

The patches of acidic gneiss which occur at Otter Head are interesting as exhibiting a rock which is very common in the acid eruptive complex stretching northward towards James bay, often in considerable areas. It is my opinion that this acid gneiss represents a much metamorphosed quartz-porphyry or the metamorphosed plutonic equivalent of a quartz-porphyry, and that it is of the same age as the Lower Huronian acid schists. My reasons for thinking that this gneiss is of the same age as the Lower Huronian schists are:

(1). All around the contact of the post-Huronian granite with the Lower Huronian schists, we find these areas of gneiss, and there seems often to be gradual transition between the true gneiss and the schist inclusions, similar to but more metamorphosed than those schists outside the granite. (See north of lake Charlotte).

(2). There is no evidence of greater straining of the minerals composing the gneiss than of the minerals composing the quartz-porphyry schists.

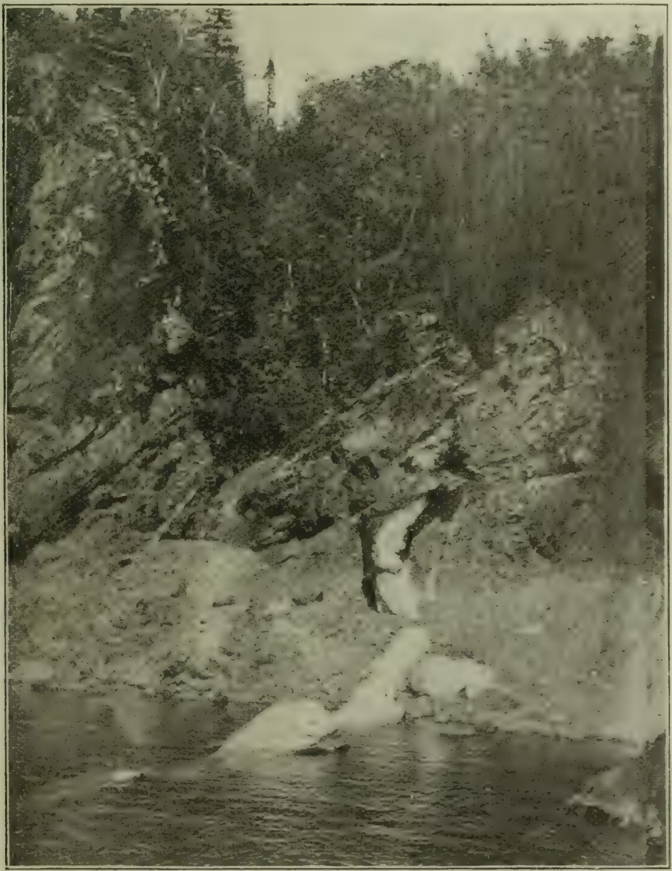
(3). There seems to be no unconformity at the base of the Lower Huronian (if for that matter we know what rocks of the Lower Huronian lie at its base).

I have mentioned the fact that there is found very commonly in the Doré conglomerate a certain sort of granite pebble very characteristic of that formation, and that no earlier granitic rock is known which could have supplied these pebbles. Now this granitic rock must either have been entirely removed or completely covered by later rocks, or else have changed its state, been re-fused or re-granitized. It can hardly have been altogether removed or covered because the area is large and the granite pebbles of this sort occur everywhere within the Doré conglomerate. In favor of the hypothesis of a change of state there seems to be visible support in the many areas of acid gneiss within the granites,[16] and in the fact that these gneisses wherever they occur, have a peculiar irregular contact with the granite, as if the gneisses had been re-fused or in some way re-crystallized. Perhaps the word "re-granitization" is better than "re-fusion" since in our present knowledge of granites it is not known whether or not they are a product of fusion. Thus the areas of gneiss may represent the metamorphosed remnant of the rock, from which the granite pebbles of the Doré

[16] These areas of acid gneiss greatly predominate over the granites in the acid igneous complex, especially northward away from the contact. The gneisses and granite are generally classed together as Laurentian and are often very difficult to separate; but it will be understood that the granites and allied rocks are considered Post-Huronian--the gneisses, Lower Huronian.

conglomerate were derived. During the folding of the Huronian rocks and in the main the direct result of it, came the re-granitization of the Lower Huronian acid igneous rocks, which must have existed in quantities largely predominating all other rocks and the consequent intrusion of vast masses of granites and allied rocks. This is rather too large a question to be considered here in further detail.

Most of the quartz and calcite veins which appear in Michipicoten were the direct result of the granitic intrusions. Some smaller quartz veins must have existed before Upper Huronian times, as evidenced by the presence of quartz pebbles in the Doré conglomerate. The post-Huronian veins are probably for the most part of the type of fissure veins. Veins are rare in northern Michipicoten, but they are of common occurrence in the western area. Just at Otter Head there is an interesting vein of



Big quartz vein, Lake Superior shore, near mouth of Pucaswa river.

orthoclase and calcite, parallel with the structure of the gneiss in which it is enclosed, and with a width of from eight inches to one foot. Several prominent quartz veins outcrop on the point between the mouth of the Imogen river and the Pucaswa river in a soft felsite schist. One vein containing both pyrites and chalcopyrite, is about 3 feet 6 inches wide at its widest part near the lake shore, from which it narrows in either direction. To the north about seventy-five feet another vein appears, and this may be the same as the one just described from which it has been faulted, the plane of the fault being occupied by a diabase dike. A short distance still farther north along the shore another vein appears prominently both above and below the

water. It rises as a ridge two or three feet high above the gravel of a small bay, and four or five feet beyond in the enclosing schists. It is three feet wide and dips vertically, lensing out upward in the schists. Both veins are apparently quite barren.

Small calcite veins are common in schists along the walls of the falls near the mouth of the Pucaswa river. From the Pucaswa river southeastward along the shore numerous veins show up, in some of which a little prospecting work has been done, but nothing of commercial value obtained. A small calcite and quartz vein about one mile from the mouth of the Pucaswa river was found to carry gold to the value of $4.40 to the ton, and copper to the extent of 3.85 per cent. A specimen from another vein of quartz near a small shack on the lake shore about five and a half miles southeast of the mouth of the Pucaswa river on analysis gave traces of gold.

A somewhat remarkable mass of quartz occurs near the mouth of the Eagle river, which I believe was originally staked as an iron location. Its width is about forty feet and its length is traceable for about a hundred and twenty-five feet, disappearing in either direction beneath the drift. In character it is often stained rusty or red by iron oxides, again it appears kaolinic or jasperoid, at other times it resembles greenish chert. It seems to cut the enclosing green schists, but these are much contorted and this relation could not be definitely ascertained. Stringers of calcite traverse the quartz mass in one place at least. Sometimes the mass appears brecciated

A deposit of molybdenite is found in a coarse-grained quartzose pegmatite on the shores of Molybdenite lake on the route between Michipicoten Harbor and the Frances mine. I was unable to visit the locality during the past summer, but I understand that the deposit is not of commercial importance, as proven by some exploration work done on the property some years ago.

THE POST-HURONIAN BASIC ERUPTIVES

In northern Michipicoten the post-Huronian basic igneous rocks are apparently never effusive, but eruptive. They have a wide though limited distribution throughout the entire area, and being the youngest rocks in the district, they cut all the lower formations, including the post-Huronian acid eruptives. They occur as numerous narrow dikes cutting the sediments and enclosing rocks, as elongated bosses included within the schists, conglomerate and granites, and as narrow sheets, generally offshoots from the wider bosses, especially apparent when occurring within the Helen iron formation. Sometimes the dikes are of economic value, along the iron ranges, by creating dams against which iron ores may be deposited by iron-bearing solutions passing down troughs leading to the dikes. The sheets on the other hand are usually detrimental by retarding the lateral flow of iron-bearing solutions, and by giving a smaller area from which ferruginous material can be drawn.

The most important bosses are those intrusive in the schists and granites north of and southeast of Paint lake, that one occurring south of lake Michi-Biju and extending east to Katzenbach lake, and that one cutting the schists and Helen formation near David's lakes. The sheets are most evident at Brotherton hill, and along the MacDougall promontory at Iron lake, where their occurrence within the iron formation has already been briefly mentioned. The narrow dikes are seen commonly everywhere, and are especially evident along the Lake Superior shore.

Petrography of the Basic Eruptives

All the post-Huronian basic rocks are of the gabbro family and consist essentially of a light colored pyroxene, probably diopside, of a basic plagioclase (maximum extinction | 32° on 010) and of more or less magnetite or ilmenite. With these primary minerals are usually associated a variety of secondary minerals. The pyroxene is frequently replaced by the paramorphic amphibole, uralite, and less commonly by

biotite. Chlorite is the principal final product of alteration. The plagioclase alters to mixtures of epidote, quartz, muscovite and carbonate. Olivine, though rarely seen, is in some few places quite common, and serpentine often indicates its former presence. Most of the bosses and wider dikes away from the influence of the iron formation show fairly fresh, very little strained rocks, but the sheets and dikes connected with the Helen formation are always extremely changed and consist of a structureless mass of chlorite, epidote, decomposed felspars, quartz, leucoxene, and carbonate. These metamorphosed rocks are often with difficulty recognized as of igneoous origin. The extreme phase is seen in the chloritic sideritic schists which intercalate with the iron formation at Iron lake and elsewhere, and many of which were at first sight considered as sedimentary rocks.

From a textural standpoint the basic eruptives show several facies. The most common of these are the coarse-grained granitoid phase, and the finer grained sometimes aphanitic ophitic phase. Lamprophyric rocks are rare.

The granitoid type is represented by the true gabbros or dolerites. These, often coarsely crystalline, are the prevailing rocks in the larger bosses and show no especially remarkable features. Frequently they are altered to epidiorites, and their margins are often strongly magnetic.

The ophitic type is shown in the diabases, which sometimes occur as a textural differentiation on the edge of the larger gabbro bosses, and also in many of the smaller bosses, in all the smaller dikes, and in most of the intrusive sheets, though as has been said, the original character of all dikes and sheets occurring within the iron formation has been lost.

INDEX

REPORT OF
THE BUREAU OF MINES, 1905
PART II.

(SECOND EDITION.)

THOS. W. GIBSON, Director

THE COBALT-NICKEL ARSENIDES AND SILVER DEPOSITS OF TEMISKAMING

BY

WILLET G. MILLER, Provincial Geologist

With an Appendix on the "Early History of the Cobalt Industry in Saxony," translated by Geo. R. Mickle.

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1906

Map of
Cobalt-Nickel-Arsenic-Silver Area near Lake Temiskaming, Ont.

To accompany Report of W. G. Miller.
IN FOURTEENTH REPORT OF THE BUREAU OF MINES,
1905
THOS. W. GIBSON, DIRECTOR.

Scale 1 mile to 1 Inch.

NOTES

The lot numbers are in Arabic numerals, 1, 2, 3, etc., Each lot, where it does not border on water, or on an irregular boundary, contains, theoretically, 320 acres; or one half of a square mile. Only alternate north and south lines are run, or blazed, between lots, but posts are planted at every half mile on the east and west lines. The concession numbers are in Roman numerals, I., II., etc.

Mining claims are numbered thus: J. B. 1, R. L. 400, etc., the initials representing the surveyor's name. Mining claims, forty acres in size, on lots which were surveyed prior to the location of the claims are not numbered, but their boundaries are shown on the map.

Character of Surface. Most of the southern half of the mapped area contains green timber. Lumbering operations have been conducted over all this area with the exception of the Lumsden and Booth timber berth. Much of the field is covered with drift deposits, and the exposures of compact rock are frequently clothed with moss. The outlines of the various formations shown on the map must therefore be considered to be only approximately correct. It is felt that the areas shown as Keewatin, colored green, are perhaps in some cases not correctly mapped. In the field it is difficult, at times, to distinguish these greenstones from the slaty-greywackè member of the Lower Huronian, especially if the latter has been subjected to pressure. Only a rapid traverse was made through the timber berth which lies immediately to the east and to the south of the Montreal River. The surface is uneven. Hills with steep faces frequently rise to a height of a hundred feet or more.

Prospecting. A prospector entering the district in search of cobalt-silver deposits should first make himself familiar with the various classes of rocks shown on the map, otherwise he may spend his time on the least promising outcrops. Good exposures of the Keewatin greenstones are to be seen along the shore of Lake Temiskaming immediately to the south of Haileybury, and along the line of railway between Cobalt lake and Bass lake. The latter exposures contain numerous small cracks filled with white calcite, which assist in distinguishing these rocks from the near-by rather massive greywacké slates of the Lower Huronian. A typical variety of the diabase or gabbro, later in age than the Huronian, is to be seen in the first rock cut on the railway south of Haileybury. Between this cut and Cobalt station there are several exposures of the conglomerate, with granite and other pebbles, and of the slate-like rocks of the Lower Huronian. A good contact between the latter series and the Keewatin, with porphyry dike, is exposed on lot 15, concession II. of Bucke, on the shore of Temiskaming. The Lower Huronian here rests on the Keewatin and contains pebbles and angular fragments of greenstone and porphyry, thus clearly showing the unconformity between the two series. A contact of the Lower Huronian with the middle Huronian is to be seen on lot 4, concession XII. of Lorrain. Angular blocks, or shingle, of the former are cemented in the arkose of the latter.

The terms Lower and Middle Huronian are here used provisionally. The formations have not been correlated with those to which the names are applied in the vicinity of the north shore of Lake Huron and elsewhere.

A great variety of minerals is found in the veins, and the prospector should visit some of the working properties near Cobalt station and become acquainted with the general character of the ore. The following is a list of minerals which have been found in the veins. If any of these are strange to the prospector, he should procure a text-book of mineralogy and read descriptions of them.

Ores. The chief ores are native silver, smaltite or diarsenide of cobalt, niccolite or arsenide of nickel, chloanthite or diarsenide of nickel, associated with which are argentite or sulphide of silver, pyrargyrite or sulph-antimonide of silver, dyscrasite or antimonide of silver, erythrite or cobalt bloom, annabergite or what may be called nickel bloom, millerite or sulphide of nickel, native bismuth, tetrahedrite or sulph-antimonide of copper and other metals, mispickel or sulph-arsenide of iron, and occasionally graphite. Erythrite and annabergite are the hydrated arsenates of cobalt and nickel, respectively. They are both decomposition products. Asbolite and other minerals of similar origin are present. The more common minerals, galena, copper pyrites, iron pyrites and zincblende, together with oxide of manganese, occur in small quantities, especially in the country rock. Other minerals are found, but generally in such an impure form that their characters have not been definitely determined. Calcite is the chief vein stone, but some of the veins have little even of it. Quartz and fragments of the wall rock are found in some of the ore.

The outcrops of the veins usually show native silver and cobalt bloom. The latter is a good indicator, its delicate pink color having a striking appearance. It is apt to be confused only with certain tints of red oxide of iron. If the bloom is, however, carefully heated, which can be done in the cover of a tin can over a camp fire, it will be found to turn blue. If fused with borax it imparts a beautiful blue color to the resulting glass. The native silver exposed at the outcrops will, of course, be tarnished. Its color can be determined by cutting it, and its weight is characteristic. Native bismuth, with fresh surfaces, looks like silver, but is more easily cut, and on exposure tarnishes a reddish color. The other important mineral in the above list which is not brittle and is easily cut is argentite. Prospectors have mistaken it for lead, but it is black in color.

The veins are narrow, the width of the ore averaging, in the veins which have been worked, probably 10 or 12 inches, and may be easily passed over by those accustomed to prospecting in other fields. Fragments of rock should be frequently broken off the ledges. Bloom has been discovered by this means in outcrops where its presence was not suspected. Cracks in rocks should be cleaned out with a prospecting pick. A vein of these ores, a few inches in width, is worth much labor.

Shipments. From the veins which have been opened up in an area, which is less than one mile in length from north to south, and about one half mile in breadth from east to west, surrounding Cobalt station on the recently constructed Temiskaming and Northern Ontario Railway, something over $800,000 worth of ore was shipped, up to 30th June, 1905. With one exception, the vein on the north of R. L. 404 near Cobalt lake, all of these veins carry high values in silver, besides important amounts of cobalt, nickel and arsenic. The composition of shipments (carloads) from one of the silver-bearing veins (1), and from the vein which does not carry silver values (2) is seen from the following results of analyses:—

(1)	Per cent.	(2)	Per cent.
Silver	11.41	Cobalt	15.60
Cobalt	11.27	Nickel	7.00
Nickel	3.78	Arsenic	61.74
Arsenic	44.16		

Silver brings about 60 cents per Troy ounce. and about 90 per cent. of the value is paid for the metal in the ore. Cobalt has sold for 60 to 65 cents, nickel at 12 to 15 cents, and arsenic at about 1 cent a pound, in the ore.

Veins. The veins occupy almost vertical cracks or fissures which cut across the beds of the, usually, slightly inclined conglomerate-slate series of the Lower Huronian. From the map it will be seen that there are three isolated belts of these rocks, with a strike approximately northeast and southwest, between the east shore of Sasaginaga lake and a line joining the northeast end of Giroux lake with the southeast end of Cross lake. Veins have been found in all of these belts.

The veins, however, do not all have the same strike. Those on J.B. 6, J.B. 7 and that near the southwest corner of R.L. 404 strike approximately east and west, while those on J.S. 14 and J.B. 1 strike more nearly northeast and southwest. On the north end of R.L. 404 the vein strikes approximately southeast and northwest. These veins are indicated by the sign —•— on the map, the line showing approximately the direction of the strike.

It may be added that there are one or two exceptions to the statement that the silver-cobalt ores occur in the Lower Huronian rocks. Near the southwest corner of Cross lake, for example, native silver has been found in diabase or gabbro, and cobalt bloom occurs in a similar rock on the north end of lot 2 concession III. of Dymond and on the south end of the lot across the road to the north. In both cases the diabase has been at one time overlaid by the Lower Huronian which in all likelihood contained veins. The last mentioned locality is over eight miles north of the deposits near Cobalt station. Cobalt bloom has also been found staining the Keewatin, at the shore of Temiskaming in the southeast corner of Bucke. It is the writer's opinion, however, based on the discoveries already made, that the prospector for silver and cobalt should confine his attention practically to the Lower Huronian series.

THICKNESS OF LOWER HURONIAN

Since the Lower Huronian is simply a fragmental series—at one time in the form of gravel and other materials in a state of finer division, which were deposited on the eroded, uneven surface of the Keewatin and Laurentian—it becomes of importance to know what thickness any of this series, filling old valleys and depressions, has. All that can be said on this point is that the exposures on the hills near Cobalt station are about 500 feet higher than similar ones at the shore of Temiskaming, low water level. The series may therefore in some places have a thickness of at least 500 feet. Before erosion took place it was undoubtedly much thicker.

DISTRIBUTION OF ROCKS

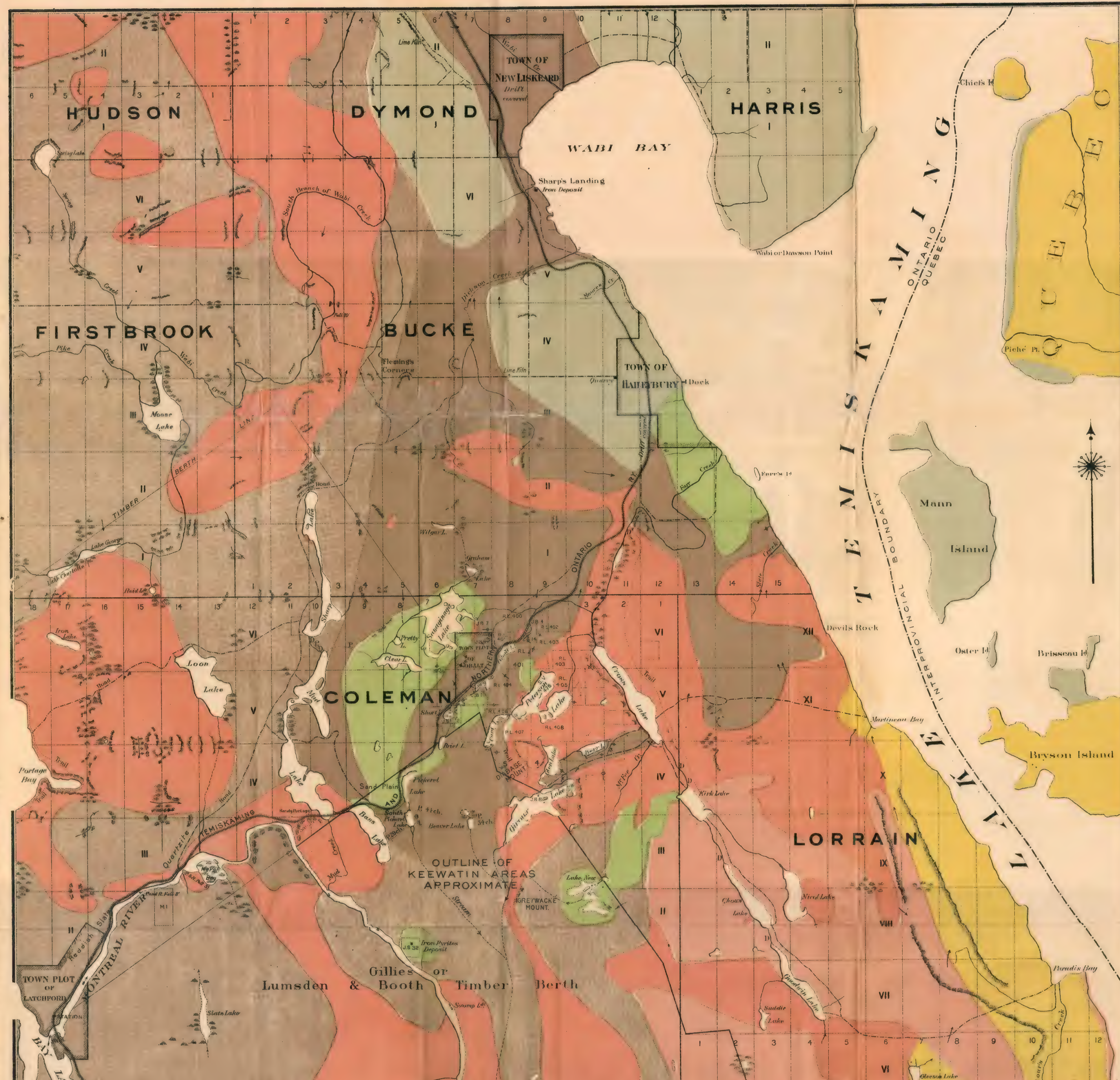
Isolated outcrops of these Lower Huronian rocks in this part of northeastern Ontario are found in an area which stretches for a distance of about 75 miles, from south of Lake Temagami to the height of land, and westward for a considerable distance. It remains to be determined whether cobalt-silver deposits of economic value are to be found in many of these outcrops. Cobalt ores have recently been found in small quantities 30 miles north of Cobalt station and about the same distance to the south. The ores are thus known to occur at points along a north and south line which has a length of 60 miles.

ORES OF THE KEEWATIN

The Keewatin, which is also extensively developed in this part of Ontario, contains characteristic economic minerals. It is the series in which the iron ore formations of Temagami, and the township of Boston 75 miles to the north, occur. An outcrop, only about 25 feet in length of a similar ore is found at Sharp's Landing near the shore of Temiskaming. This outcrop is part of a buried iron range which runs northwestward into the township of Hudson, where large angular blocks of it are found in the conglomerate of the Lower Huronian, and in all probability beyond. From the map it will be seen that this iron range is buried pretty deep in parts of its course. At Sharp's Landing it is overlaid by the Lower Huronian. A little farther westward the Niagara limestone and thick deposits of recent clays tend to bury the range still deeper, and it is also cut across by the tongue of diabase which traverses this part of the field.

On location J. S. 32, on the Montreal river, an iron pyrites deposit is found in the Keewatin. Near Temagami, twenty miles or so to the southward, two mispickel deposits carrying gold are being developed. It is interesting to note that the arsenic in the Keewatin is combined with iron, in mispickel which is gold-bearing, while the arsenic compounds of the Lower Huronian are essentially those of the other magnetic elements, cobalt and nickel, and are associated with silver. These ores of Temagami and near Cobalt station should warrant the erection, at some point along the railway, of an arsenic refining works, which could treat the ores of both localities.

Cobalt station is distant, by railway, 103 miles from North Bay Junction on the Canadian Pacific Railway, and 330 miles from the City of Toronto. Sudbury lies about 90 miles, in a straight line, southwest of Cobalt station.



SECOND EDITION, SEPTEMBER, 1905.

COLORS AND SIGNS

T. and N. O. Ry.
Wagon Road.
P. Portage.
D. Dam.
R. Rapid.
T. Trail.
Swamp
Hills
Veins

NIAGARA. *Limestone with a small amount of sandstone and conglomerate at its base.*

GREAT UNCONFORMITY.

PRE-CAMBRIAN.

DIABASE AND GABBRO. *These Igneous rocks cut through all the other pre-Cambrian series in the field. Their exact age is not known. They may belong either to Animikie or Keweenawan time. The fissures now occupied by the cobalt-silver ores in the Lower Huronian were probably formed by the disturbance which accompanied the eruption of the diabase and gabbro. The ores may have been deposited from highly heated mineral laden waters associated with the eruption.*

MIDDLE HURONIAN. *Lorrain arkose, quartzite and conglomerate.*

UNCONFORMITY.

LOWER HURONIAN. *The Cobalt series, consisting of conglomerate, breccia, quartzites and greywacké-slate. Outcrops of the coarser varieties of the rocks are confined almost entirely to the area east of a line which runs from the east side of Mud Lake northeastward to about lot 6 in the fifth concession of Bucke. West and southwest of this line there is much reddish banded slate and quartzose greywacké.*

The cobalt-nickel-arsenic-silver veins occur in this series.

GREAT UNCONFORMITY.

KEEWATIN. *This series is an igneous complex, consisting of greenstones, quartz-porphyries and other rocks. It has been more or less folded and disturbed. The series is of economic interest owing to the fact that the iron ranges of northeastern Ontario, the Temagami mispickel deposits and other ore bodies occur in it.*

IGNEOUS CONTACT.

LAURENTIAN. *Lorrain granite. This granite is intrusive into the Keewatin but not into the Lower Huronian.*

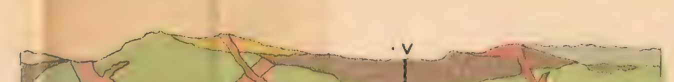
WORKING MINES

The first properties from which ore was shipped have the following numbers on the map:—

Trethewey Mine	=	J. B. 7.
La Rose Mine	=	J. S. 14.
McKinley & Darragh Mine	=	J. B. 1.
Cobalt Hill Mine	=	R.L. 404, northwest corner.
Little Silver Mine	=	R.L. 404, southwest corner.

More recently other properties in the vicinity of Cobalt, Glen and Kerr lakes have become producers.

Cobalt bloom and related minerals have been found 30 miles north of Cobalt station in the northern part of the township of Ingram and adjacent territory. Similar minerals have been found 15 or 20 miles to the south and southwest. The productive area is, however, confined to within about two miles of Cobalt station. Recently ores similar to those of Cobalt, but containing gold instead of silver, have been found in small quantities at Rabbit lake, 30 miles south of Cobalt.



Ideal vertical section to show the relations of the rocks on the map together with the cobalt-silver vein, V, in the Lower Huronian.

SOURCES OF INFORMATION

Geologically surveyed by WILLET G. MILLER and CYRIL W. KNIGHT, 1904.

Temiskaming map sheet, 1897, by ALFRED E. BARLOW of the Geological Survey of Canada.

Plans of surveys by the Crown Lands Department of the Province of Ontario.

NOTES ON THE LAKES

The heights of different lakes above mean sea level are given as follows (in feet) by Mr. James White, Dominion Geographer: Temiskaming 578 (low water), Sharpe 905, Mud 900. The height of Sasaginaga is given by Dr. Barlow as 968, Clear lake as 978 and Loon lake 903. On the railway profile the track at Cobalt station is shown to be at an altitude of 980 feet above sea level. The greatest depth of water found in Cobalt lake, at low level, was about 40 feet. The surrounding lakes with the exception of Temiskaming, are also shallow.

PRODUCTION.

According to returns made to the Bureau of Mines, there were shipped from the mines in this area up to 30th June 1905, 1049 tons of ore, the contents of which were as follows:

	Quantity	Value
Silver, ounces	1,297,455	$689,045
Cobalt, tons	81	100,520
Nickel, do	46	12,454
Arsenic do	353	3,496
Total		$805,515

The ore therefore averaged over $767 a ton

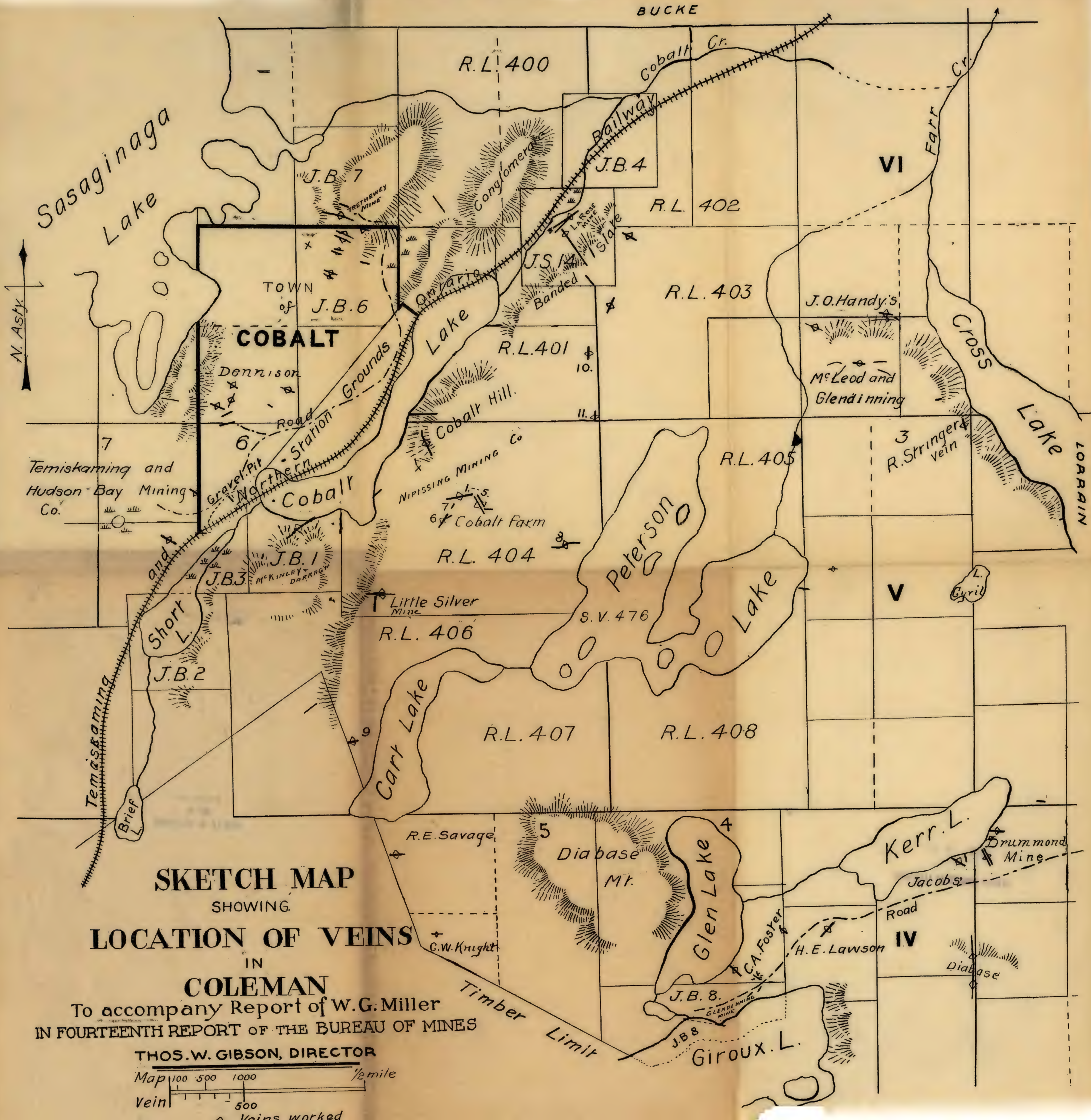

SKETCH MAP
SHOWING
LOCATION OF VEINS
IN
COLEMAN
To accompany Report of W. G. Miller
IN FOURTEENTH REPORT OF THE BUREAU OF MINES
THOS. W. GIBSON, DIRECTOR
Map 100 500 1000 ½ mile
Vein 500
Veins worked
BUCKE
LORRAIN
N. Asty.
Sasaginaga Lake
R.L. 400
R.L. 401
R.L. 402
R.L. 403
R.L. 404
R.L. 405
R.L. 406
R.L. 407
R.L. 408
J.B. 1
J.B. 2
J.B.3
J.B.4
J.B. 6
J.B. 7
J.B. 8.
J.B 8
J.S.14
S.V. 476
TOWN of
COBALT
Dennison
Road
Gravel Pit
Temiskaming and Northern Ontario Railway
Station Grounds
Cobalt Lake
Cobalt Cr.
Cobalt Hill
Conglomerate
Banded Slate
Trethewey Mine
La Rose Mine
Temiskaming and Hudson Bay Mining Co.
Nipissing Mining Co
Cobalt Farm
McKinley-Darragh
Little Silver Mine
Short L.
Brief L.
Peterson Lake
Cary Lake
Cross Lake
Farr Cr.
J. O. Handy's
McLeod and Glendinning
R. Stringer's vein
L. Cyril
VI
V
IV
R.E. Savage
Diabase Mt.
Glen Lake
C.W. Knight
C.A. Foster
H.E. Lawson
Kerr L.
Drummond Mine
Jacobs
Road
Diabase
Glendinning Mine
Giroux. L.
Timber Limit

Fig. 1. The Little Silver Vein, southwest corner of location R. L. 404. The cliff is about 70 feet in height, and is composed of almost horizontally lying Lower Huronian rocks. At the bottom are about 15 or 20 feet of well banded greywacké-slate. This is followed by about the same thickness of feldspathic quartzite, overlying which, at the top of the cliff, is a coarse conglomerate. The greatest thickness of the vein, as originally exposed, was about 8 inches. The strike is east and west, and the dip, as the photograph shows, is almost vertical.

REPORT OF
THE BUREAU OF MINES, 1905
PART II.

(SECOND EDITION.)

THOS. W. GIBSON, Director

THE COBALT-NICKEL ARSENIDES AND SILVER DEPOSITS OF TEMISKAMING

BY

WILLET G. MILLER, Provincial Geologist

With an Appendix on the " Early History of the Cobalt Industry in Saxony," translated by Geo. R. Mickle.

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1906

"The detection of a small portion of cobalt in association with these metals upon the shores of Lake Huron, should lead us to look for deposits of this rare and valuable material."—T. Sterry Hunt in Report of Geological Survey of Canada for 1848-9

WARWICK BRO'S & RUTTER, Limited, Printers,
TORONTO.

PREFACE TO THE SECOND EDITION.

Owing to the wide interest which has been taken in the Cobalt mineral deposits, not only in Canada but throughout North America, and in parts of Europe, the first edition of 6,000 copies, published in November last, is now nearly exhausted. Since it is necessary to issue the present edition at an earlier date than was expected there has been little opportunity to revise either the text or the accompanying colored geological map. The first edition of the map consisting of 6,000 copies was published in April, 1905, in time for the prospectors who were then entering the field. It was thought that another edition might not be required until the heavily wooded and moss-covered surface was sufficiently cleared so as to enable the geology to be worked out in greater detail than was possible during our examination of the area in 1904. It is evident, however, from the exhaustion of the edition that the map has served most of the needs of prospectors. As the number of men in the field, all of whom will need maps, seems likely to be greatly increased during 1906, it has been thought best to issue a slightly revised edition without waiting until more field work has been done.

On account of the variety and relationship of the rocks outcropping in the area it is not possible to prepare an approximately perfect map without very detailed work. This is especially true of the localities in which outcrops of Keewatin and Lower Huronian are associated. The latter group is derived largely from the former, and the two are frequently so intimately connected that a very large scale map would be needed to represent them accurately. Frequently exposures of Lower Huronian, only a few feet in diameter, overlie the Keewatin. On the other hand small exposures of the Keewatin project through the Huronian. Again, the slaty members of the Lower Huronian resemble, especially when they have been metamorphosed by intrusion of diabase, the more characteristic phases of the Keewatin, rendering it almost impossible to distinguish certain facies of the one from the other in the field. If, however, the prospector reads carefully the marginal notes on the geological map and visits the typical outcrops of the Keewatin and Lower Huronian, there mentioned, it is believed he will have little difficulty in most cases in distinguishing the one group of rocks from the other. Prospecting during the coming season will be carried on miles outside of the boundaries of the geological map, but if the prospector on first entering the field visits and studies some of the more typical outcrops of rocks in the Cobalt area proper, he will be able to recognize, in most cases, similar rocks which cover a large territory in this part of Ontario.

Post-Middle Huronian basic rocks, of the composition of diabase, of at least two and possibly more ages, are known in the field. It is desirable, since important cobalt-silver veins occur at two or three points in the diabase, that these should be studied more carefully than they have been up to the present time.

Origin of Ores

The writer has little to add concerning the source of the ores to what was said in the first edition. Whether the ore minerals were carried from great depths by the heated, impure waters associated with—following—the diabase eruption, or whether they were leached from the Keewatin greenstones, is a problem which in all likelihood may never be conclusively solved. As stated on a following page, analyses of specimens of Keewatin and later diabase give no clue as to the source of the metals. Diabase in the surrounding region, as for example in the township of Dymond, ten miles north of Cobalt station, and in the township of Ingram, thirty miles to the north, has been found to contain cobalt in veinlets, with little or no silver. The diabase here is of

Huronian age. Hence one might conclude that the lack of silver in these veinlets was due to the absence of the Keewatin. That this conclusion would not be correct is seen from the fact that the Keewatin in the vicinity of Trout lake, and eastward south of Bay lake on the Montreal river, contains at a number of points considerable cobalt, but, in so far as the writer knows, little or no silver is here associated with the cobalt. Since the diabase and Keewatin cobalt deposits so far discovered outside of the Cobalt area proper do not contain silver in paying quantities, must we look to another rock as the source of this metal? The Laurentian granite of the township of Lorrain, outcrops of which are not known much nearer than two miles from Cobalt station, would be the only other source. It scarcely appears, however, that this granite is closely enough associated with the ore bodies to be the source of the silver. Masses of granite may, on the other hand, be buried beneath the Huronian sediment in the immediate vicinity of the productive silver area surrounding Cobalt. On succeeding pages attention is drawn to three old and now practically exhausted mineral areas of Europe, the veins in all three of which resembled very closely those of Cobalt, Ont., especially as regards their width, all being very narrow, and their mineral contents. In the case of one of these localities, at least, that of the Chalanches, it has been sugegsted by an eminent authority, who has studied the veins, that the cobalt and nickel were derived from the basic rocks and that the silver probably came from the leaching of deep-seated granite. In the case of the other two localities, Annaberg and Joachimsthal, it has been thought that the ores are genetically connected with the granite.

A plan showing the striking relationship which the three isolated areas—those of Rabbit lake, to the south, Cobalt lake, in the centre, and Wendigo lake, to the north—have to the great northeast-southwest lines of weakness in the area is given (Fig. 15).

Depth of Veins

Little can be said in addition to what has been stated in the first edition concerning the depth to which the values in silver, cobalt and nickel will continue. At the La Rose mine, which is on the most important vein yet exploited, it has been proved that native silver exists at the depth of about 200 feet from the surface. The maximum depth to which veins on other properties have been tested is only about eighty feet. Judging from the experience of other districts, which contain veins with a similar assemblage of ores, native silver will be found in larger quantity in the upper workings than in those at a greater depth. This was the case at Silver Islet on Lake Superior, at the Chalanches, at Annaberg and Joachimsthal, and in other localities, where native silver has been worked. It seems pretty clear that in most veins the native silver is a secondary product, formed by the decomposition of the sulphide and other compounds. While silver in the free state will probably become less abundant as the veins are worked to a greater depth, the reverse will likly be true of its compounds. At Silver Islet, which was worked to a depth of about 1,200 feet, the chief production came from the first four levels. At the Chalanches it was not found profitable to work the veins to a great depth. At Annaberg and Joachimsthal, on the other hand, narrow veins similar in width and mineral contents to those of Cobalt, have been worked profitably to a depth of between 1,500 and 2,000 feet. The writer, on general principles, would not expect the values in the veins at Cobalt, except as regards their content in metallic silver, to change materially so long as the veins continue in one series of rocks. That is, if a vein is worked in Lower Huronian rocks, as the majority of them are, its values should not change materially until the bottom of the basin in which these rocks lie is reached. Or if a vein is followed from the surface in diabase, its values should continue not only in this rock but also, from what one can say at present, into the Lower Huronian as well, if it underlies the diabase, as it does in many parts of the field. The horizontal extent of any vein, if it can be determined, should form some criterion as to the depth to which the vein can be followed.

Markets and Refining

During the last two or three months, although more ore has been mined than during a similar period heretofore, less has been marketed. This is owing to the difficulty experienced by the company, which was practically the only buyer of the ores, in treating the material so as to extract all the valuable contents. Recently ore has been sold for its silver content alone, nothing being received for the cobalt, nickel or arsenic, thus entailing great loss on the mine owners. This state of things cannot long continue. Similar ores have long been successfully treated elsewhere, and although the processes employed in the extraction of the metallic contents are kept more or less secret, the difficulties in making use of them or in employing others are not insurmountable.

The statistics of production are not complete owing to the fact that comparatively little ore has been shipped during the last two or three months, on account of the state of the markets. Adding together the value of what has been shipped with that now stored at the mines, the output can be estimated at approximately $2,000,000 during the year just closed.

Changes in Text and Figures

A few illustrations have been added to this edition (Figs. 2, 15, 17, 32, etc.) Some additions have been made to the text. The quantity and value of the shipments of cobalt-silver ores during 1905 is given.

An interesting account of the "Early History of the Cobalt Industry in Saxony," summarized by Prof. Geo. R. Mickle from a German publication, will be found in the appendix.

Reviews

A number of mining and geological journals have published reviews of the first edition. Among these reviews are those in the Engineering and Mining Journal of New York, Mining World of Chicago, Canadian Mining Review of Ottawa, and in the recently founded journal of Economic Geology of South Bethlehem, Pa. The last mentioned review is by Dr. C. K. Leith, of the University of Wisconsin, who has made a special study in several fields of the group of rocks found in the neighborhood of Cobalt, where he has also spent some time.

Benefits and Injuries

The discovery of the rich ore bodies at Cobalt came at an opportune time for the northeastern part of the Province of Ontario. The Government railway, the Temiskaming and Northern Ontario, is being built northward into a vast territory which needs settlers. Not many miles northward of Cobalt the rocky region, traversed by the railway for the first hundred miles of its course, gives place to a promising agricultural district. Farther north, over the height of land, the railway taps the great clay belt which has been estimated to contain 16,000,000 acres of fertile lands. Cobalt has served, and will serve, as the lodestone to this great region in the vicinity of Temiskaming and northward. Its discovery during the building of the railway was thus fortunate. The cobalt-silver veins here serve the purpose which the auriferous placers of Australia, California and British Columbia served in their day. They attract not only miners but all classes of people, and will thus bring about the settlement of the region much earlier than would the stable yet comparatively prosaic industries of farming and lumbering.

Cobalt has convinced the public that Ontario has deposits of ore richer than are those known in most parts of the world. The discovery in northern Ontario of economic minerals of any grade of richness will not be doubted in the future. It will be different from the history of Cobalt, which although described in both the daily press and in technical journals, shortly after its discovery, received little attention from the public

for nearly eighteen months. If the ore bodies had been in some remote region difficult of access its history as regards recognition would likely have been otherwise. There would have been a stampede to it.

Although the Province of Ontario has thus far benefited greatly by the discovery of Cobalt, both as regards the attention which it has directed to our minerals and the advertisement which it has been for the undeveloped resources in general of our north country, it is to be feared that another period of stock-jobbing may be ushered in. The ignorance, credulity and superstition of many people is vast concerning mining enterprises. A few rich ore bodies are discovered in a district, hundreds of worthless claims are represented as being promising, and a "boom" is launched. People buy so-called mining stocks, and forever after are cynical concerning the mineral industry. That a boom has baneful effects on the mineral industry is patent to all mining men in this country. Since the collapse of the boom which began in the 90's it has been almost impossible to raise capital on mining enterprises no matter how promising they can be proved to be. It is to be feared that a similar state of affairs will exist in two or three years if a boom is now started in connection with the Cobalt area. As regards this field one thing should be remembered. It is this,—that while certain claims have been passed by the inspectors, there is no evidence, in many cases, that these properties will ever become dividend payers. It should also be remembered that it takes little capital at Cobalt to prove the quality of most claims, and that a majority of those staked will prove barren. Companies do not need to be capitalized at high figures. No part of the world to-day offers better opportunities for legitimate mining enterprises than does Ontario and Canada in general. It is to be hoped that the industry will not receive another set-back through mining on paper.

W. G. M.

Toronto, February, 1906.

COBALT-NICKEL ARSENIDES AND SILVER

BY WILLET G. MILLER

Introduction

What is known as the Archean protaxis, or that rugged, rocky region which stretches away from the St. Lawrence river, expanding to the northwestward, and occupying a large part of northern Ontario, has produced and is constantly producing, a group of what may be called unique, or at least comparatively rare, economic minerals. Probably as great a variety of minerals is produced here in proportion to the number of inhabitants as is derived from any other country. Among these economic deposits are:

The nickel mines of Sudbury, which is one of the two important nickel producing localities of the world, with the bye-products, platinum and palladium;

The corundum deposits of north Hastings, south Renfrew and other areas in eastern Ontario, which now supplies by far the greater part of the corundum consumed in the world;

The unsurpassed feldspar and mica deposits of Frontenac and adjoining counties and the apatite, graphite, pyrite, talc, gold, copper, zinc, lead, fluorite and barite of the same district;

The iron ranges, which extend over a great territory in northern and northwestern Ontario, but which, up to the present, have not been developed to a great extent.

In addition to these, it may be said that a few years ago north Hastings possessed the only arsenic plant in North America. More recently the auriferous-arsenic ores of Temagami were made known, and lastly a discovery has been made of the series of Cobalt-Nickel Arsenides and Silver, which are unique, so far as known, on this continent, and are paralleled by deposits only in Saxony and adjacent regions of continental Europe.

The eastern part of this region is also noted for certain minerals which can scarcely be said to be of economic value, but are of great scientific interest. The largest and finest crystals of the mineral zircon in the museums of the world come from eastern Ontario, as do also sphenes, pyroxenes, scapolites and other crystals. Sodalite, marble and other decorative materials are also found here.

Situation and Discovery

A brief description of the character and modes of occurrence of the Cobalt-Silver ores of the area examined during 1904 is given, as marginal notes, on the colored geological map which accompanies this report. For practical purposes, it is not necessary to add much to these. In the report which was published in the Thirteenth annual volume of the Bureau of Mines an account of the discovery and location of the ore bodies was given. It may be well to repeat briefly some of this information.

These ore bodies which carry values in silver, cobalt, nickel and arsenic, were discovered during the building of the Temiskaming and Northern Ontario Railway. In fact, it may be said that the railway discovered the deposits, as it runs almost over the top of what is probably the most important vein yet found.[1] The finding of such rich

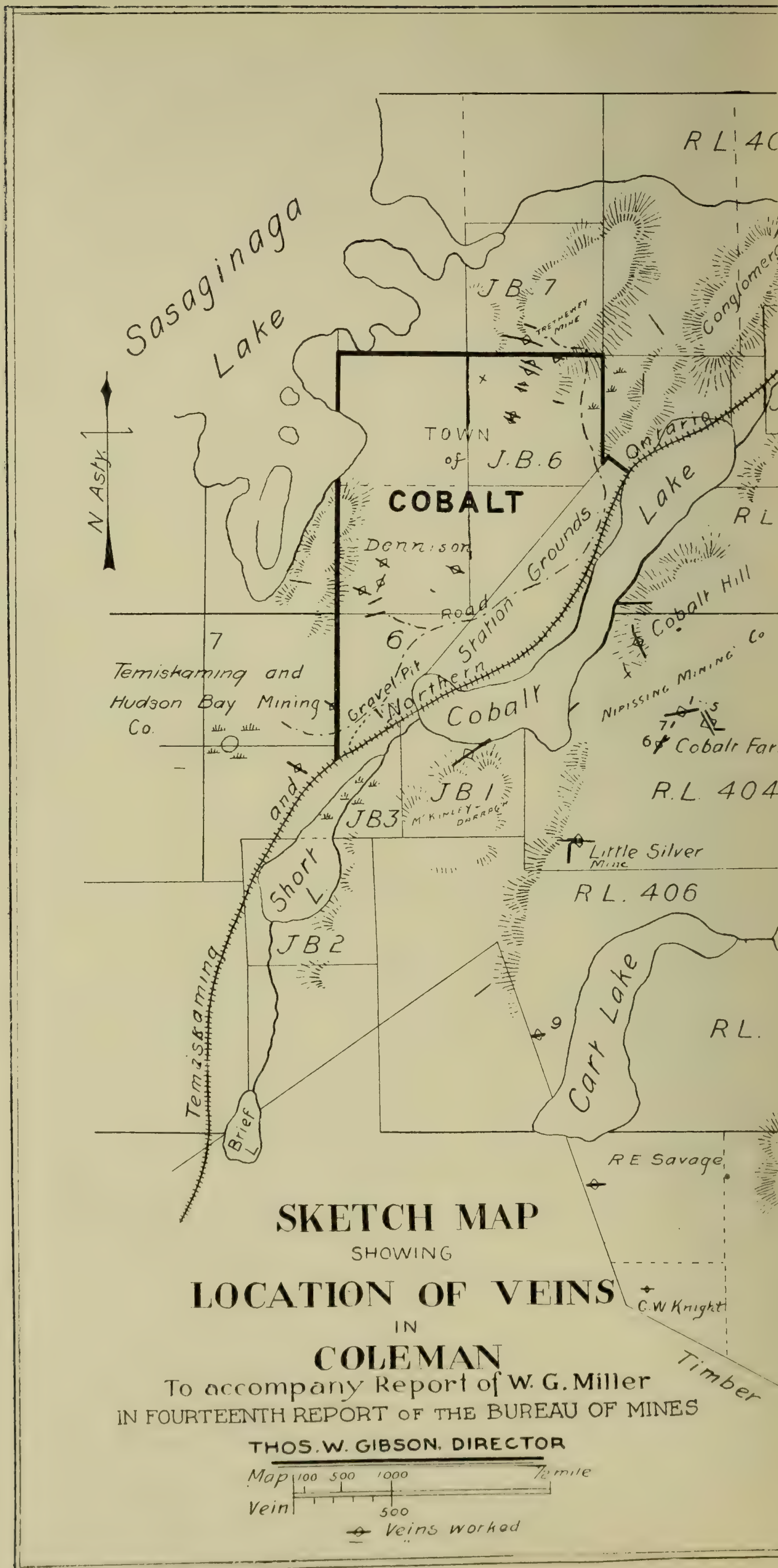
[1] It may be added that the Canadian Pacific railway virtually discovered the Sudbury nickel deposits, 90 miles to the southwest of Cobalt. It can thus be said that each of the two railways, thus far built in this part of Ontario, brought to light an important and little dreamed of mineral field.

A FORECAST.

It may be interesting to note that the writer made the following comment on the mineral possibilities of the district in a report over two years before the discovery of the Cobalt deposits—

"It will be seen from what has been stated on preceding pages that the district examined contains as great a variety of rocks as probably any part of the Province of equal area. . . . .

"Although few discoveries of economic minerals have been made in this territory, it may reasonably be expected, judging from the character and the variety of the rocks, that deposits of value will be found when the district is more carefully prospected, as it will be in a short time, owing to the rapid settlement which is now taking place . . . . It would seem that at least some of the conditions of the Sudbury district are repeated in this more eastern field." (Report on "Lake Temiskaming to the Height of Land" in the Eleventh Report of the Bureau of Mines, page 229.) This report gives an account of the rocks and of the canoe routes from Lake Temiskaming northward to the Height of Land, and may now be found to be of service to prospectors.



SKETCH MAP
SHOWING
LOCATION OF VEINS
IN
COLEMAN

To accompany Report of W. G. Miller
IN FOURTEENTH REPORT OF THE BUREAU OF MINES
THOS. W. GIBSON, DIRECTOR

Map 100 500 1000 ½ mile
Vein 500
Veins worked

BUCKE
Cobalt Cr.
Railway
J.B 4
R.L. 402
Slate
T.S. 14
Banded
R.L. 403
401
VI
Farr Cr.
J.O. Handy's
McLeod and Glendinning
Cross Lake
3
R. Stringer's vein
R.L. 405
Peterson Lake
S.V 476
V
Cyril L.
407
R.L. 408
LORRAIN.
5
4
Diabase Mt.
Glen Lake
Kerr L.
Jacobs Road
C.A. Foster
H.E. Lawson
IV
Diabase
J.B 8.
JB8
Giroux L.
Limit

ore within so short a distance of the shore of lake Temiskaming, a stretch of water which has been a well-travelled route to the north by white men for 200 years or more, and the deposits being only about four miles from the town of Haileybury, show the possibilities there are for the discovery of important mineral-bearing areas in the vast hinterland of Ontario, much of which is little known. The first of these ore bodies to be worked lies within half a mile of what is now known as Cobalt station, distant by rail 103 miles from North Bay junction on the transcontinental line of the Canadian Pacific, and 330 miles almost north of the city of Toronto.[2] It may also be added that one of the oldest know ore bodies in North America, the argentiferous galena on the east side of lake Temiskaming, is distant only 8 or 9 miles from Cobalt station. This galena deposit was apparently discovered by voyageurs 150 years ago. A map of the lake published in 1744 has a bay marked on it with the name "Anse à la Mine," thus showing that the deposit was known at least at that date, and probably much earlier, owing to the fact that the ore outcrops at the water's edge and is of such a character as to attract attention (Fig. 2).

Some of these veins in the vicinity of Cobalt station were apparently noticed by the men employed in railway construction in the spring of 1903, but, there being no miners or prospectors among them, little interest was aroused and nothing was heard of the discovery by prospectors till October of the same year. At that time Mr. T. W. Gibson, Director of the Bureau of Mines, then in that part of the Province, was given a sample of niccolite which the donor thought was copper ore, the color of this mineral being like that of copper as the German name, kupfer-nickel, indicates. Mr. Gibson, however, recognized the value of the sample and forwarded it to the writer, who was then in the eastern part of the Province, and asked him to make a report on the occurrence as soon as possible. The writer, although he knew the specimen represented high class ore, hardly expected to find ores of the character and in the quantity which he saw on his arrival.[3] This mineral, niccolite, had been found

[2] The name cobalt appears to come from the German *Kobold*, meaning goblin or house spirit. The metal was so called by the miners because its ore, being arsenious, was poisonous and difficult to treat. The writer felt, however, when he suggested the name for the town, that in this age such a name would not be considered unlucky.

THE CHRISTENING OF THE TOWN OF COBALT.

Fearing that the name "Long Lake," which had been in use for the construction camp, would be retained for the station which it had been decided to place at this point on the railway, the writer endeavored to select a name which would be in keeping with the locality. As an experiment he put up a post, in the first week of June, 1904, on the railway near the lake and wrote on a piece of board attached to the post, "Cobalt Station, T. & N. O. Ry." The name took at once, as was seen when the writer visited Haileybury a few days afterwards. The workmen and others from Long Lake who had registered at the hotel in the meantime had all given their address as "Cobalt."

On the 7th of June, 1904, the writer wrote to Mr. T. W. Gibson, Director of the Bureau of Mines, concerning the name of the station.

EXTRACT FROM LETTER FROM W. G. MILLER TO T. W. GIBSON.

"I wish you would suggest to the Commissioners of the T. & N.O. Ry., or whoever has the naming of the stations along the line, that they call this station at Long Lake, Cobalt Station." "There will be a post office here in time—there are enough people here for one already—and there is now a Long Lake post office in Frontenac County. The name "Cobalt" would be unique. It would serve to advertise the place and miners and others would not get mixed in their stopping off place, as they might if the station is simply called 'Long Lake.'"

On June 11th, Mr. Gibson wrote to the Secretary of the Railway Commission, Mr. P. A. Ryan, concerning the calling of the station "Cobalt." Two days afterwards on June 13th, Mr. Ryan wrote as follows to Mr. Gibson:

"I beg to acknowledge receipt of your favor of the 11th inst, suggesting that the station which will probably be established at Long Lake, south of the Township of Bucke be called "Cobalt." The suggestion which you make strikes me as being a good one, and I shall have pleasure in bringing your letter before the Commission at the proper time."

Shortly after the receipt of Mr. Ryan's letter the Commissioners met and accepted the name "Cobalt" for the station, which is now known, probably, at least as widely as Dawson City and the Klondike.

[3] At the time of the writer's arrival in the district, in November 1903, 4 veins, all of which were very rich, had been found. Three of these were within sight of the railway and the fourth was a short distance to the southeast. The blackened, tarnished silver had up to that time attracted little or no attention, although it occurred in profusion in two or three of the weathered outcrops. At the present time over 40 veins and stringers, the majority of which can be worked at a profit, have been found. They are distributed over approximately 25 forty-acre lots, and are in the hands of 16 or 20 individuals or companies. Other veins are being found every few days. Although the writer's first report of his examination of this cobalt-silver area was published in November, 1903, the public evinced little interest in the field until about eighteen months afterwards, when reports were made of shipments from various properties. The lack of interest was apparently due to the fact that the evil effects of the mining boom of a few years ago had not died out, and the public were more or less sceptical of reports on mining, no matter from what source they might emanate. By June, 1905, interest was aroused in the district throughout North America, and the rush to Cobalt has been greater than has been seen before in the mining fields of Ontario.

The following extracts from letters written in the autumn of 1903 by Mr. T. W. Gibson, Director of the Bureau of Mines, may now have some historical interest.

some years before in association with the lower grade nickel ores of some of the Sudbury deposits, but no great quantity of it has up to the present been discovered in the Sudbury field, the town of which name lies about 90 miles southwest of Cobalt station. It may, however, be stated that the Sudbury ore deposits are quite different in character and in origin from those at Cobalt, although the metal nickel is an economic constituent in each. The Sudbury deposits have received a great deal of attention from geologists during the last fifteen years or more, and two important reports have recently been published on them. These are by Dr. A. E. Barlow, of the Geological Survey, and by Professor A. P. Coleman, of this Bureau. Nearly all the writers agree that the ores are essentially of igneous origin,—that is, that the nickeliferous magnetic pyrites or pyrrhotite and copper pyrites have separated from a molten mass of rock. The deposits at Cobalt, on the other hand, occupy narrow, practically vertical fissures or joints which cut through a series of usually slightly inclined metamorphosed fragmental rocks of Lower Huronian age (Fig. 1). A few veins, of similar form, have also been found in the adjacent diabase. Some of the recently discovered veins near the centre of location R. L. 404 appear to be partly or wholly in the Keewatin, which is here in contact with the Lower Huronian.

The material in these veins has, in all likelihood, been deposited from highly heated and impure waters which circulated through the cracks and fissures of the crust and were probably associated with—followed—the post-Middle Huronian diabase and gabbro eruption.[4] It is rather difficult to predicate the original source of the metals—silver, cobalt, nickel, arsenic and others—now found in these veins. They may have come up from a considerable depth with the waters or they may have been leached out of what are now the folded and disturbed greenstones and other rocks of the Keewatin. Analyses of various rocks of the area have not given a clue as to the origin of the ores. As these ore bodies in the vicinity of Cobalt station may be said to be unique among those known in North America, we have no chance of instituting comparisons on this continent. Some European veins, however, such as those of Annaberg, Joachimsthal and other localities which will be again referred to, show a similar association of minerals. The origin of these has been explained by most authors by the supposition that the metals were leached from the surrounding rocks. The writer has found, however, from the descriptions which have been published of most of these European occurrences, that there are usually basic dikes in the vicinity of the veins. These dikes appear to have,

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(Extract from letter from T. W. Gibson to W. G. Miller, then inspecting mineral properties in the vicinity of Perth, Ont.).

"Bureau of Mines, Toronto, Oct. 26th, 1903.

"I am enclosing herewith a fragment of a larger sample of what I take to be kupfer-nickel found along the line ot the Temiskaming & Northern Ontario Railroad. The locality of the deposit is in the unsurveyed territory immediately south of the township of Bucke. I have not learned anything as to the extent of the discovery, but if the deposit is of any considerable size, it will be a valuable one on account of the high percentage of nickel which this mineral contains. I think it will be almost worth your while to pay a visit to the locality of the discovery before navigation closes. I am under the impression that the find was made while making the cutting for the railway. Mr. Ferland, of Haileybury, showed me a sample of the mineral when I was there, but he did not appear to recognize it or know its value, deeming it a compound of copper. It would be rather remarkable should our nickel deposits turn out to have a wider range than has hitherto been supposed, and especially if the new outcrop should be a large one containing ore of so high a grade."

(Extract from letter from T. W. Gibson to W. G. Miller, addressed to Haileybury.)

Bureau of Mines, Toronto, Nov. 13th, 1903.

"I duly received your letters of the 6th and 9th inst., respecting the progress you are making in looking up the really wonderful finds which appear to have been made in the locality where you are. I hope you will be able to procure a first-class set of samples for the Bureau from all the discoveries, and am waiting with some degree of anxiety your report on the western deposit, namely, the one at Loon Lake."

On November 16th, 1903, the Toronto "Globe" had a half-column article, based on letters of W. G. Miller to to the Bureau of Mines. The following sentences indicate the tenor of the article: "Rich discoveries along government railway. . . . Exceeding rich in nickel. . . . Silver, cobalt and arsenic also found. . . . One specimen of silver obtained by Mr. Miller was about the size of his hand, and half an inch thick."

On November 20th another half column article, an interview with W. G. Miller, appeared, in which are these sentences, "Temiskaming minerals . . . Prof. Miiler returned with samples. Says there is no doubt as to the importance of the find. . . . One large piece of silver weighs about ten pounds."

Interviews of this date also appeared in several other Toronto newspapers.

[4] The waters are said to be associated or connected with the diabase eruption in the sense that they probably represented the end product of the eruption. In many volcanic regions hot springs are present long after the the rocks have solidified. In the Cobalt area the fissures and joints now occupied by the ores were probably produced by the gradual shrinkage in cooling of the diabase, the ores being deposited by the waters which represented the last stage of vulcanicity.

in some cases, the same relation to the ore bodies that those of diabase and gabbro have in the Ontario cobalt region.

Ores and Minerals.

The more important ores in the veins under consideration are native silver,—associated with which is usually some dyscrasite, argentite, pyrargyrite and other compounds of the metal—smaltite, niccolite and related minerals. Many of the minerals occur mixed in the ores, and for this reason some of them have not been clearly identified. Another character of the minerals which renders their identification difficult, is the fact that most of them occur in the massive form. Crystals when present are small, being almost microscopic in size. The writer has, however, identified the following minerals, which can be conveniently classed under the headings:

I.—Native Elements:
Native silver, native bismuth, graphite.

II.—Arsenides:
Niccolite, or arsenide of nickel, $NiAs$; chloanthite, or diarsenide of nickel, $NiAs_2$; smaltit, or diarsenide of cobalt, $CoAs_2$.

III.—Arsenates:
Erythrite, or cobalt bloom, $Co_3\,As_2\,O_8+8H_2O$; and annabergite, or nickel bloom, $Ni_3\,As_2\,O_8+8\,H_2O$.

IV.—Sulphides:
Argentite, or silver sulphide, Ag_2S; millerite, or nickel sulphide, NiS.

V.—Sulph-arsenide;
Mispickel, or sulph-arsenide of iron, $Fe\,AsS$; cobaltite, or sulph-arsenide of cobalt, $CoAsS$.

VI.—Antimonide:
Dyscrasite, or silver antimonide, Ag_6Sb.

VII.—Sulph-antimonides:
Pyrargyrite, or dark red silver ore, $Ag_3\,SbS_3$; tetrahedrite, or sulph-antimonide of copper, $Cu_8Sb_2S_7$.

In addition to the above minerals there are a number of secondary or decomposition products with rather indefinite characteristics, such as asbolite, which may be called a much weathered form of cobalt bloom. It consists essentially of the oxides of cobalt, manganese, etc. The cobalt bloom and annabergite occur intermixed, at times, in proportions such that the red color of the former counteracts the green color of the latter, a white clay-like substance being the result. There are occasionally other sulphides present than those mentioned, especially in the wall rock. These consist of copper pyrites and bornite, which are the sulphides of copper and iron; galena, the sulphide of lead; and iron pyrites, the disulphide of iron. Zinc blende is found occasionally. These minerals in the wall rock were probably deposited before the vein materials.

One is struck with the great variety of these comparatively rare minerals, some of which occur in a high percentage in the deposits. The number of metals is also large.

A characteristic of the group is the subordinate part which sulphur plays in comparison with arsenic. Antimony, which is not abundant, is found in some compounds where we would expect to find arsenic, since the latter is so much more abundant. For instance, while we have both native silver and arsenides in abundance, no compounds of arsenic and silver have yet been recognized, although they are probably present. Then one would also expect to find some compounds of bismuth since this metal occurs in the free state in considerable quantities in some parts of the deposits. It might also be expected that native arsenic would occur at times.

It will be seen from a following page that nearly all the chemical groups of minerals found in the celebrated Joachimsthal deposits of Bohemia are present in the Temiskaming ores. The most important exception is uraninite or pitchblende, which came into prominence a few years ago on account of its being the chief source of the element radium. The Austrian Government finding they had a practical monopoly of pitchblende are reported to have prohibited its export.

The Bohemian deposits appear never to have been so rich in silver, cobalt, nickel or arsenic as are those of Ontario.

Fig. 2. Map published in 1744 showing that the argentiferous galena deposit on the east side of Lake Temiskaming (Ance à la Mine) was known at that date

Fig. 3. View of part of Cobalt, showing railway station and hotel, December, 1905.

NOTES ON MINERALS

The 5 or 6 veins, with one exception, which were the first to be worked, all carry high values in silver, as do those discovered more recently. The outcrop of the non-silver bearing vein was about 14 inches in width of practically solid ore, which had a gray color and was not unlike mispickel in appearance, (Fig. 6). Very little veinstone, such as calcite, or quartz, was present. When examined carefully in hand specimens, this apparently massive, uniform, gray ore is found to contain two constituents. Set through the gray round mass are grains of the copper colored niccolite, the ground mass itself being smaltite. Occasionally this ore in tiny vugs shows crystals large enough to be recognized. Minute crystals of smaltite also occur in the wall rock. No crystals of the niccolite have been recognized. There are probably some other closely related arsenides of cobalt in addition to smaltite in this ore. The diarsenide of nickel, chloanthite, is also present. At times some massive tetrahedrite is seen, and it is usually associated with copper pyrites, which helps one to identify it. It is, however, usually readily recognizable by its black color and bright appearance.

Much of the surface of this ore shows the decomposition product, cobalt bloom, the arsenide having been changed by atmospheric agencies to the arsenate, the oxidized form. There is at times some green decomposition material, which is the arsenate of nickel, known as annabergite. Occasionally the cobalt bloom shows a crystalline structure, being in the form of delicate rosettes. The bloom, which is of a delicate pink color, can be easily recognized, if one has any difficulty in distinguishing it from certain shades of red oxide of iron, by heating it gently, when it will take on a blue color. This is characteristic of all hydrated salts of cobalt. They are pink or, if in dilute solutions, almost colorless. Sympathetic ink, for instance, is a dilute solution of cobalt salt. If a pen be dipped into it and used for writing on paper, the writing is invisible until the paper is heated, driving off the water and dehydrating the salt, which then takes on a distinct blue color.

In most of the veins where silver is found in important amounts, a uniform massive structure like that of the vein just referred to is not exhibited. There is more or less calcite present, and at times a little quartz. The veins sometimes show a crudely banded structure. The writer is, however, unable to say that there is any special arrangement of the ores in these veins.

The ores are frequently grown together. Arsenides of cobalt and nickel, for example, have native silver intimately mixed with them; at other times there is almost massive smaltite or niccolite. Some of the veinlets which form junctions with the larger veins contain much silver in various forms. The chloanthite occurs characteristically in small spheroidal masses in calcite.

The native silver is in masses and also occurs in films, flakes, sheets and wire-like forms, especialls in calcite. On analysis it is found to contain, usually, some antimony and occasionally bismuth. The dyscrasite is usually closely associated with native silver. Pyrargyrite is not very abundant, and only one slab or angular piece of ore which the writer examined contained crystals of this mineral. These were of sufficient size to be examined with a reflecting goniometer. Fig. 4 represents one of these crystals which has been kindly measured by Professor Goldschmidt, of the University of Heidelberg. The pyrargyrite is rather easily recognized by the color of its streak. Argentite occurs in a number of the veins, and is easily recognized by its softness, cutting like lead, from which metal it may be distinguished by its black color.

Only one sample containing the delicate needles or hair-like forms of the sulphide of nickel, millerite, was found, although it is likely this mineral occurs in most of the deposits. Being so delicate, the crystals are easily destroyed.

Native bismuth has been found in all of the deposits worked. On freshly broken surfaces it has almost the color of native silver, and is not readily recognized unless it is cut. Being softer than silver, it is rather easily determined, its color distinguishing

it from argentite. Native bismuth, however, soon tarnishes on exposure to the air, and takes on a rather striking yellowish color, something like that of pyrite or bornite.

The following analyses will give some idea of the characteristics of the minerals and of the value of the shipments which have been made from a number of the deposits, the material in one vein being similar to that in most of the others.

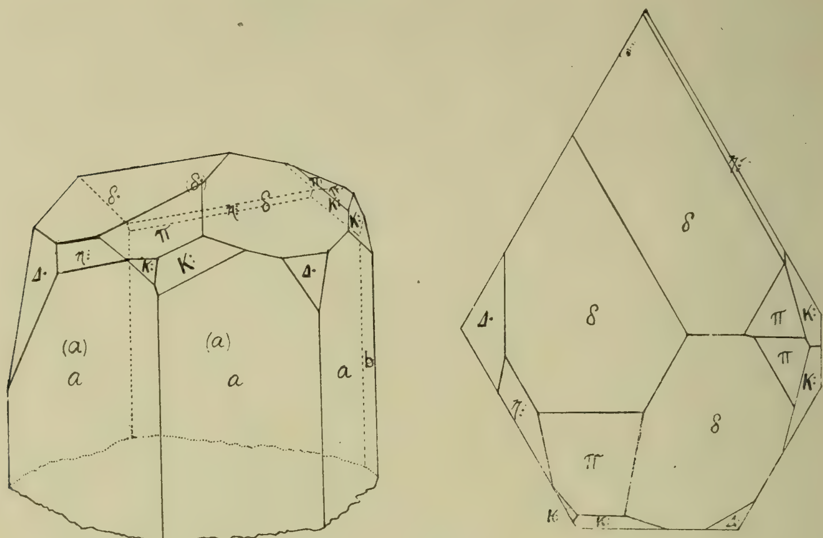


Fig. 4.

The following note on the pyrargyrite crystals from the La Rose mine is by Prof. Nicol:

"The crystals occur as an incrustation on the surfaces of chinks or cracks in the country rock intimately associated with argentite or silver glance.

"The crystals are more or less well developed hexagonal prisms, terminated in some cases by rhombohedrons and scalenohedrons. The crystal reproduced in the drawings shows a somewhat peculiar development—only five faces of the prism of the first order *a* are present; the sixth face *b* is a single representative of the prism of the second order."

Shipments and Analyses

The production for the first quarter year ending March 31st, during which shipments were made, was 354.05 tons of ore valued at $293,552. The ore thus averaged $829 a ton. The average percentage of the metals in the ore was as follows:

	Per cent.
Silver	4.802
Cobalt	8.264
Nickel	4.739
Arsenic	34.606

The 4.802 per cent. of silver represents 1,406.27 ounces a ton. The cobalt, nickel and arsenic in one car load are not included, no returns having been made.

During the second quarter, March 31st to June 30th, the shipments were 537 tons, valued at $394,552, or an average of $734 a ton.

The average percentage of the metals in the ore for this quarter was:

	Per cent.
Silver	4.158
Cobalt	6.890
Nickel	3.091
Arsenic	30.912

The metals in the ore were sold at approximately the following prices: Silver, 55 to 60 cents an oz. Troy for 90 per cent. of the contents, cobalt, 65 cents, nickel, 12 to 15 cents, and arsenic about 1 cent a pound.

During the first quarter there were four companies or individuals who made shipments, namely, Messrs. Timmins, Dunlap and McMartin, of the La Rose mine, or J. S. 14, Mr. W. G. Trethewey, of the New Ontario mine, or J. B. 7, Messrs. R. Gorman and Co., of the McKinley and Darragh mine, or J. B. 1, and the Nipissing Mining Company, who worked the Cobalt Hill and Little Silver veins in the northwest and southwest corner of R. L. 404 respectively. During the second quarter small shipments were made from one or two other properties.

Total Shipments for 1905

The companies shipping ore during the third and fourth quarters of the year 1905, in addition to those mentioned above, were the Kerr Lake Mining Company, Victoria Mining Company, Buffalo Mining Company, Trethewey & Leonard, Lawson Mine, White Silver Company, Glendenning-Blair and Kerr, Watts & Allen, Temiskaming & Hudson Bay Company, Violet Mine, Drummond Mines Ltd., O'Brien. One or two other properties had a small production. The total number of producers was seventeen.

During the second half of the year, owing to there being no plants in America adapted to extracting all the constituents of the ores, the mine owners received, in some cases, no pay for the cobalt, nickel and arsenic contents, the purchasers allowing for the silver only. For this reason the statistics of production received by the Bureau of Mines are incomplete, complete analyses not having been made of some shipments. In compiling the following table the average of the cobalt, nickel and arsenic contents in the shipments analyzed has been taken, and proportionate percentages, based on the silver, in the shipments of which complete analyses were made, has been added to those which were incompletely analyzed.

Owing to their receiving nothing for some of the metallic contents of the ores, if sold during the latter half of the year, the producers had stored at their mines on December 31st, 1905, the end of the year represented by the statistics, a considerable quantity of ore. In two or three cases the quantity in storage represented a value of $100,000 or more. The following table, therefore, does not represent the total production for 1905, but merely the shipments:

	Quantity.	Value.
Tons of ore shipped	2,144	
Silver, ounces	2,441,421	$1,355,306
Cobalt, tons	118	100,000
Nickel, tons	75	10,525
Arsenic, tons	549	2,693

The 2,144 tons of ore shipped during the year had therefore a percentage composition of: silver 3.90, cobalt 5.50, nickel 3.49, arsenic 25.60. A percentage of silver of 3.90 represents 1,138.72 ounces a ton, or at 64 cents an ounce, the present price of silver, a value of $728.78 a ton of ore throughout the year. It is needless to say that the average value of the ore shipped from few mining camps can equal this. The average value of the total metallic contents per ton of ore shipped throughout the year, at the prices received, was $684.94. It should be noted that most of the ore mined during the past year came from near the surface. Hence the percentage of cobalt, nickel and arsenic is lower than it will be where greater depth is reached, the metals being leached out by surface agencies.

The ore shipped up to the present has been sorted by hand. Much ore that would be considered high grade in most mining camps is accumulating on the dumps. This will no doubt be milled in the not distant future and will add materially to the output. Further reference is made on page 20, under the heading of Veins, to the value of shipments.

It will be of interest to add the following to the shipments of 1905, 158 tons being shipped in 1904.

Cobalt Output in 1904

Silver, ounces	206,875	$111,887
Cobalt, tons	16	19,960
Nickel, tons	14	3,467
Arsenic, tons	72	904
Total		$136,218
Ore shipped, tons		158

The uses made of cobalt and a table showing the production of the metal in various countries are given on following pages. The uses of arsenic are also mentioned.

Exhibit of Cobalt-Silver Ores

Through the Bureau of Mines, arrangements were made for securing a collection of the cobalt-silver ores for exhibition at the Louisiana Purchase Exposition, held at St. Louis in 1904. These were obtained at the request of Mr. William Hutchison, Dominion Exhibition Commissioner, who has since purchased the samples exhibited with the object of keeping them as a permanent exhibit. They were afterwards sent to the Liege Exhibition, Belgium.

The following notes given to the writer by Mr. W. E. H. Carter, late Provincial Inspector of Mines, show the composition and character of the exhibit. While the exhibit was at St. Louis it was sampled by Mr. Carter, who has this to say of the various specimens: "The niccolite contains silver not only disseminated but in pure stringers and nuggets as well. These nuggets and stringers were not included in the sample taken for analysis, but should be considered as very considerably adding to the value of the ore represented by my sample.

"I. Cobalt-Silver Ore, Sample from R. L. 404:

(a) 50 lb. decomposed material with silver, containing by estimate 30 p. c. silver, which amounts to 291 oz., and at 55c. per oz. $160 05

(b) 61 pieces cobalt ore .... } 75 pieces weighing
(a) 14 pieces, wall rock with silver .... } 6,510 lb.

This 6,510 lb. contains by assay—

Silver, 2.58 oz., per ton, at 55c.	$ 4 62
Cobalt, 18.04 p. c.,—1,174.4 lb., at 65c.	763 36
Nickel, 5.52 p. c.,—359.35 lb., at 15c.	53 90
Arsenic, 39.56 p. c.,—791.2 lb., at 1c.	7 91
Total value of sample	$1,019 84

(a) From Little Silver vein, southwest corner of location R. L. 404.

(b) From Cobalt Hill vein, in northwest corner of the same location.

"II. Niccolite-Silver Ore, from La Rose mine, Location J. S. 14 on map:

Containing by asssay.	Value per ton.
Silver, 7.944 p. c.—3,089 oz., per ton, at 54c.	$1,668 06
Cobalt, 8.93 p. c.,—178.6 lb., at 65c.	116 09
Nickel, 15.67 p. c.,—313.4 lb., at 15c.	47 01
Arsenic, 39.56 p. c.,—791.2 lb., at 1c.	7 91
Total per ton	$1,839 07
There are about three tons in the sample	$5,517 21

"III. Trethewey's Cobalt-Silver Ore, Location J. B. 7 on map:

145 lb. in all. Of this, 15 lb. is by estimate pure silver—291 oz.—and at 54c.	$157 14
And 130 lb. is cobalt ore containing silver, and valued at $1.50 per lb.	195 00
Total value	$352 14

"In valuing the above ores I have taken the prices paid by the dealers at New York for the crude ore, which are as follows for the several metals:

Silver	Market value.
Cobalt	65c. per lb.
Nickel	15c. per lb.
Arsenic	1c. per lb."

The value of these samples of ore, which are to be kept for exhibition purposes, is approximately as follows:

(1) Sample of cobalt-silver ore from R. L. 404, weight 6,560 lb., value	$1,019 84
(2) Niccolite-silver ore from La Rose mine, exact weight not given, but, if it is three tons, as stated, the value of the sample is	5,517 21
(3) Trethewey cobalt-silver ore, 145 lb. in all, value	352 14
Total value of collection	$6,889 19

The cobalt is contained essentially in the mineral smaltite, which is a diarsenide of this metal. Most of the nickel in the samples occurs as the arsenide, niccolite, but some of the metal is in the diarsenide form, chloanthite. The greater part of the silver is in the native form, although the sulphide, argentite, the sulph-antimonide, pyrargyrite, and other compounds of the metal are found in the deposits.

Sample from Trethewey Mine

Through the courtesy of Mr. W. G. Trethewey the Bureau of Mines has obtained a sample, for preservation in its collection, of the richer ore from his vein on location J B 7. This sample weighs 79 lb. (Fig. 5). Drillings, obtained by boring into the sample, show it to have the following composition. The calcium and magnesium carbonate represent the veinstone. The cobalt and nickel exist as arsenides and the silver is essentially in the metallic form. Some of the iron shown in the analysis may have come from the drill.

	Per cent.
Silver	66.67
Cobalt	2.15
Nickel	41
Iron	1.60
Arsenic	7.03
Antimony	9.67
Sulphur	22
Calcium carbonate	6.72
Magnesium carbonate	1.23
Insoluble	3.29

The value of the silver in this 79-lb sample, at 64c. an ounce Troy, the present market price, is $491.55, which represents an increase of $40.39 in value since the sample was purchased by the Bureau of Mines.

White Bloom

Associated with the cobalt bloom in the weathered parts of the La Rose and other veins there is a white, clay-like material, which resembles in form the moist cobalt bloom. The writer suspected that the white color of this material was due to the intermixture of the green nickel arsenate, annabergite, sometimes known as nickel bloom, with the pink cobalt bloom. An analysis made by Mr. Burrows confirmed this

Fig. 5. Slabs of silver from the Trethewey Mine, location J. B. 7. The slab standing upright by the hammer is the 79 pound specimen referred to in the text.

opinion. It is a rather interesting occurrence. In pottery the blue cobalt compounds are used in small amounts to destroy the delicate reddish tinge due to iron in the ware. In this white bloom we see one color destroyed by another in nature.

	Per cent.
Nickel oxide	29.30
Cobalt oxide	6.43
Arsenic pentoxide	38.31
Lime	.84
Magnesia	1.12
Iron	.30
Water	24.04
Total	100.34

Mr. Burrows says: "In evaporating the solution of the metals I had a very interesting result. The solution was quite concentrated, and on cooling, green acicular crystals of the nickel compound separated out, while the solution above and around them was quite pink. The original solution before the crystallizing out of the nickel compound was quite blue."

Mixed Dark Mineral

There is a mineral, or mixture of minerals, of fairly common occurrence in some of the narrow stringers which run off from the La Rose vein and elsewhere. Some of this was sent to Mr. Burrows for analysis. He has, however, not been able to get a sample which he considers represents a single mineral. From one specimen sent to him by the writer he obtained the following percentages:

	Per cent.
Silver	57.40
Sulphur	15.94
Antimony	7.92
Iron	3.88
Arsenic	.52

Mr. Burrows afterwards analysed other samples but with unsatisfactory results. For instance, he found the following percentages of silver: 47.24, 47.38, 64.29, 62.56, 63. He also proved the presence of lead in samples examined later. In one case he got 9 per cent. of lead, and in another only about 1.8. He found these samples to show considerable free silver, which no doubt accounts for the varying percentages of this metal, and that the mineral did not look the same in all parts, some of it being of a dull lustre and other parts bright.

Chloanthite

A sample of chloanthite, in nodular form, from the La Rose mine, J S 14, was found to have the following composition:

	Per cent.
Nickel	23.24
Cobalt	4.11
Silver	2.78
Sulphur	2.18
Arsenic	67.17
Antimony	none
Total	99.48

Niccolite

A sample from the La Rose mine, consisting essentially of niccolite, was found to contain 5.02 oz. of silver to the ton, and nickel 26.64, cobalt 6.16, arsenic 45.64 per cent.

Cobalt Hill Ore

The deposit known as the Cobalt Hill Vein, in the northwest corner of R L 404, was described on page 99 of the Thirteenth Report of the Bureau. For comparative purposes it will be well to again refer to that description. The workings at this vein can be seen from the railway track on the west side of Cobalt lake. The vein was one of the four which had been discovered at the time of my visit to the district in November, 1903. The ore is unique in that unlike that of the other important veins of the area it does not carry silver in paying quantities, the values being in cobalt, nickel and arsenic. From a glance at the plan it will be seen that the strike of the vein, northwest and southeast, is unlike that of most of the other veins. Moreover, this vein contains little calcite or other gangue. It is believed that the calcite, which is found in considerable quantity in the other veins, is, for the most part, later in age than the cobalt-nickel minerals, and that it is older than most of the silver at least. The silver frequently occupies cracks in the calcite.

The more or less well banded slaty greywacké, through which the Cobalt Hill vein cuts perpendicularly, dips westward towards Cobalt lake at an angle of 20 or 30 degrees in the direction in which the vein strikes. The rock is slightly arched over the vein, thus producing a gentle anticline, which pitches towards the lake (Fig. 6). The vein is at a height of 100 feet above the lake.

At the points where it was originally exposed, the vein showed a width of 14 inches of massive ore, and vugs two feet or more in the wall rock from the edge of the vein contained cobalt bloom. It may be added that in certain of the other veins the wall rock is impregnated with native silver, which is found even in the centre of boulders of granite in the conglomerate.

Fig. 6. Cobalt Hill vein, northwest corner of location R. L. 404. The photograph shows the fractured character of the rock and a gentle anticline. The vein is seen to be in step-like forms as if it had been affected by horizontal faults, but the ore is not brecciated.

The ore has a rather dark-gray color. When closely examined it is seen to be composed of a grey mineral, which is chiefly smaltite, set through which are grains of a reddish mineral, niccolite. Smaltite and the corresponding arsenide of nickel, chloanthite, are said by most authors to pass into one another by the substitution of cobalt for nickel and *vice versa*. Niccolite, in the analyses quoted by Dana and others, carries only a small percentage of cobalt and iron, while smaltite frequently contains a considerable percentage of nickel and iron. In the ore under consideration the cobalt and nickel appear to be, for the most part, in distinct compounds. In the analysis (No. 1) if we consider the 7 per cent. of nickel to exist as niccolite, and the percentages of iron and cobalt, 6.3 and 16.8 respectively, to represent smaltite, the theoretical percentage of arsenic in the ore should be 68.47 instead of 69, as found by analysis. The percentage of niccolite by weight would be 15.94, or about one-seventh part of the whole by volume, since niccolite has a somewhat higher specific gravity than smaltite.[5]

[5] Specific gravities: niccolite 7.33-7.67, smaltite 6.4-6.6, native silver 10.1-11.1.

Specimens of this ore, when examined with the magnifying glass, appear to agree with this.

Constituent.	1	2	3	4	5
Cobalt	16.8	16.7	16.76	19.80	21.70
Nickel	7.0	6.8	6.24	4.56	
Iron	6.3	7.5	....	6.20	8.89
Arsenic	69.0	62.0	66.60	60.30	63.55
Sulphur		7.0	3.37	4.09	5.38
Insol. silica, etc.	0.9	....	....	2.40	0.60
Water	....	....	....	2.00	....
Totals	100.0	100.0	....	99.35	100.12

Of the above analyses, Nos. 1 and 2 were made by Mr. O. S. James. The former represents a hand specimen from near the surface, and the latter a specimen from a depth of about 20 feet; 3 and 4 are of average samples collected by the writer, the former from the uppermost opening on the hill, and the latter from the middle or main opening, the analyst being Mr. A. G. Burrows. Sample 3 contained considerable cobalt bloom. Analysis 5 is by Dr. J. Waddell. It represents a specimen collected by Prof. Nicol. This specimen was not taken, like 3 and 4, with the object of determining the average composition of the vein. Prof. Nicol states that a qualitative analysis showed the presence of small amounts of copper and lead, and the absence of antimony, bismuth and zinc.

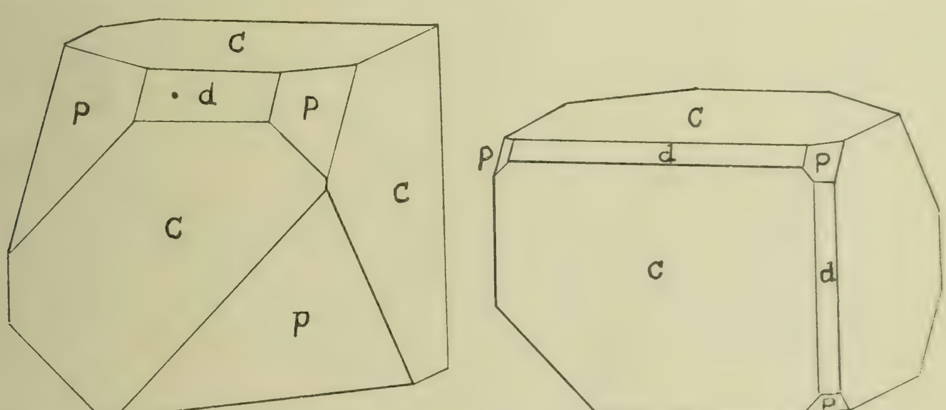


Fig. 7. Smaltite crystals from the Cobalt Hill vein, measured and drawn by Prof. William Nicol of the Kingston School of Mining. C=cube, P=octahedron, d=r. dodecahedron.

Minute, brilliant, silver-white, or tin-white, crystals, occur sparingly, imbedded in the wall-rock and in the ore. The crystals are cubes and combinations of this form, with the rhombic dodacahedron, and octahedron. Prof. Nicol, who has measured some of those on the goniometer, has found them to be smaltite, (Fig. 7). The white or gray colored arsenides show a tendency to form globular or spheroidal masses, with a radiated structure. Some of these masses in calcite have a diameter of over half an inch.

The ore is at times somewhat porous, spaces being left between the globules, which are tarnished almost black on their surfaces. Where the surface of the ore has been exposed to the action of water and ice, it has a dark color not unlike that of the wall rock, bloom, the product of decomposition, having been carried away. The fresh ore is coated with a fraction of an inch of the dark decomposed material.

Small grains of quartz are found sparingly in the ore.

The proportion of nickel to cobalt in this vein is less than that in the La Rose vein. particularly.

Copper pyrites, with which is usually associated gray copper ore, tetrahedrite, is found in the deposit. Native bismuth is also of frequent occurrence.

Tetrahedrite

Mr. Burrows found a specimen of the tetrahedrite, which occur massive, to possess the following composition:

	Per cent.
Copper	36.04
Sulphur	22.86
Antimony	21.86
Zinc	8.14
Iron	9.84
Cobalt	none
Nickel	none
Lead	not det.
	98.74

Tetrahedrite is frequently met with in the Trethewey mine, J B 7. Native bismuth has been found in practically all the veins which have been opened up.

Native Bismuth

Bismuth	99.20
Cobalt	distinct trace
Nickel	trace
Iron	.40
Silver	trace
Arsenic	trace
Antimony	none
Total	99.60

This analysis represents a sample from the Cobalt Hill vein.

Veinlets at Lake Shore

Two veinlets outcrop near the water level on the east side of Cobalt lake, not far from the point where the north boundary of location R L 404 meets the shore. A sample was taken from these veinlets and was found to have the following composition, showing that it is much like the massive ore of the vein in the northwest corner of R L 404:

	Per cent.
Cobalt	17.84
Nickel	4.16
Arsenic	56.10
Sulphur	5.98
Iron	9.22
Insoluble	4.32
Bismuth	No indications
Silver	"
Antimony	"
Water	Not determined

Sample shows cobalt bloom.

Mispickel and Cobaltite

Mispickel is not so common in the deposits as one might expect it to be. In some of the veins on what is known as the Longwell or Denison claim, in the town plot of Cobalt, mispickel seems to be a characteristic mineral.

	(1)	(2)	(3)
Iron	34.4	26.76	28.83
Arsenic	46.	41.76	40.08
Sulphur	19.6	17.63	19.25
Cobalt	......	3.21	4.83
Nickel	......	.76	......
Silver	......	......	306.1 oz. per ton.

No. 1 analysis shows the theoretical composition of mispickel; Nos. 2 and 3 are analyses of mispickel from the south vein (of the two discovered in 1904) on the Longwell location. This ore occurs in the Lower Huronian not far from the contact with the Keewatin.

In connection with these the following analyses, Nos. 1 and 2, of samples of mispickel from the Big Dan and Little Dan claims near Temagami will be of interest.

	(1)	(2)	(3)	(4)
Iron	29.68	29.84	not det.	4.55
Arsenic	36.24	36.81	41.65	44.55
Sulphur	18.99	18.77	17.8	20.73
Insoluble	13.52	13.02	not det.	
Water	.72	.79	not det.	
Cobalt	......	......	32.42	29.10
Nickel	......	......	......	.97
Total				99.90

No. 1 represents selected particles from a sample taken at the Little Dan claim. In addition to the components shown, the sample carried $4.00 worth of gold and 59 cents worth of silver per ton. No 2 represents selected particles from the Big Dan claim. This ore showed values per ton of $3.20 in gold and 54 cents in silver. The deposits are in the Keewatin. No. 3, cobaltite ore from the Benn mine, carries $5.20 a ton in gold, page 25. No. 4, crystals of cobaltite from the Columbus claim, analyzed by Mr. J. S. De Lury.

Dyscrasite

A sample of the dyscrasite from the La Rose mine was found by Mr. Burrows to have on analysis the formula Ag_6 Sb. The more common variety of this material in other districts has the formula Ag_3 Sb.

Calcite

A sample of the calcite veinstone from the Handy mine, which lies to the southwest of the foot of Cross lake, was taken by the writer and analyzed by Mr. Burrows. The vein here in in diabase. The calcite as shown by the following is remarkably pure. The absence of magnesia in calcite is rare.

	Per cent.
Lime	55.72
Magnesia	none
Iron and alumina	.12
Carbon dioxide	43.74
Insoluble residue	none
Total	99.58

Other Silver Ores of the Region

What has been known for years as the Wright silver mine is on the Quebec shore of Lake Temiskaming. It is distant about nine miles northeastward of Cobalt station and lies about seven miles northward of the village of Ville Marie. Some of the rock here is conglomerate, associated with which is porphyry. The latter is similar to rock in Minnesota which has been considered to be of doubtful origin. The ore body lies in a zone of fracture which penetrates both of the rocks mentioned. Angular fragments of these rocks, sometimes a foot or more in diameter, are cemented together by calcite and galena. The pure galena has been found to contain from 18 to 24 oz. of silver to the ton of 2,000 lbs. Iron pyrites is found in small quantities associated with the galena, and is thought to be the source of the trace of gold usually present in the ore.

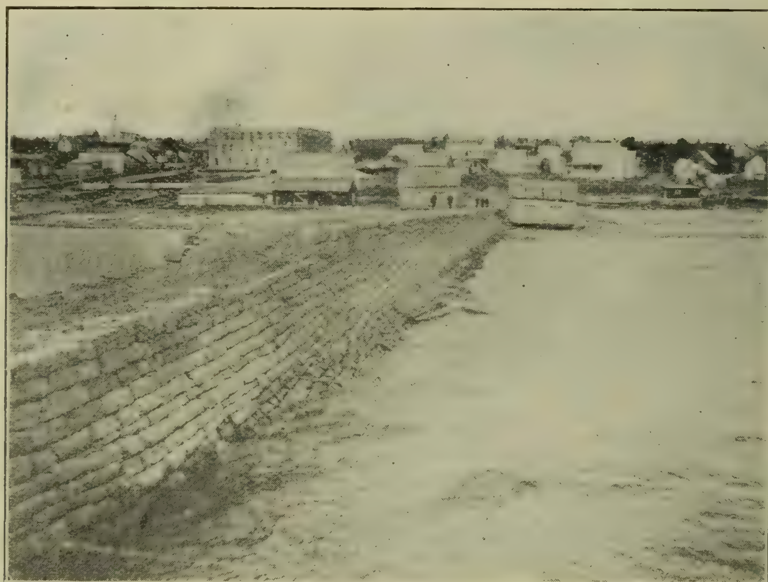


Fig. 8. The Wharf at Haileybury.

Four years ago the writer visited this mine when it was in operation. The depth of the workings, which in the lower levels had the form of a circular chamber, was said to be about 200 feet. Work ceased shortly after this and has not been resumed. The equipment consists of a concentrating plant, including jigs, tables and other machinery. There is also a small smelter on the grounds. Considerable capital appears to have been expended in experimenting. Whether the deposit could be worked at a profit under proper management does not seem to have been proved. The concentrates were shipped to Europe.

The ore body is unique. An outcrop near the water's level together with the material on the dump afford an opportunity of learning its character. Two or three rather basic dikes are seen near the workings. These are probably of the same age as the fracture zone now occupied by the ore body. The location of this mineral deposit, one of the oldest known in North America, is shown in Fig. 2, Ance à la Mine.

On Lady Evelyn and Cross Lakes

Silver-bearing galena is found at Cross lake, which lies southeast of Lake Temagami, and at Lady Evelyn Lake. According to Dr. Barlow there are quartz veins on the Matawapiki, as the last stretch of Lady Evelyn Lake, before reaching the Montreal

river, is called. These quartz veins are found here on both sides of the lake, and occur at the contact of the intrusive diabase and the banded slate, and in the latter. The minerals are galena, copper pyrites, iron pyrites, and zinc blende.

There is a deposit on an island in Cross lake, which lies immediately east of the south arm of Temagami. The minerals are galena and copper pyrites in calcite. A sample showed the following values per ton; gold $2.00, silver $9.20, copper $4.20, lead $4.00, or a total of $19.40.

Galena and copper pyrites have also attracted attention in the vicinity of the Blanche river, especially along the upper part of the north branch.

THE COBALT-SILVER VEINS

It is not considered necessary to give a detailed description of each vein in the district, the character of one being usually so much like that of another. The distribution and strike of those found up to June, 1905, are shown on the plan which accompanies this report. Many veins have since been discovered, especially on the older properties. Scarcely any of the veins have been stripped for their full length. Most of those worked have been developed in the form of open cuts. The vein first discovered on the La Rose claim, J S 14, on which several others have since been found, has been developed more systematically than any other in the district. A shaft has been sunk and about 250 feet of drifting has been done at the 90 foot level, following the vein in both directions from the shaft. The drifts prove that the vein is at least as large and rich at this depth as it has ever been. In the 250 feet the drifts have passed through comparatively little barren ground. Approximately $1,000,000 worth of ore has been blocked out of this vein.[5] As the ore body here is probably the largest yet found in the area it would not be correct to infer that smaller veins can be followed as persistently. The La Rose ore differs somewhat from that of the other veins in that it contains a higher percentage of niccolite, the nickel averaging about 10 per cent.

To give an idea of the character of the ore of one of the other veins it may be said that an open cut, about 50 feet long and 25 feet deep, on the Trethewey vein, location J B 7, has produced approximately $200,000 worth of ore, the maximum width of the vein being not more than 8 inches. The amount received for one car load of 30 tons of ore from this mine, at the prices for the contained metals mentioned elsewhere in this report, was between $75,000 and $80,000. A shipment of 50 tons of the ore gave on analysis approximately the following percentages of metals:—arsenic, 38; cobalt, 12; nickel, 3.5; and 190,000 ounces of silver. Pay was received for cobalt and silver only.

Most of the cobalt-silver veins occur in what is called on the map which accompanies this Report the Lower Huronian. A few have been found in the diabase. There is no reason, so far as the writer can see, why the veins should not also occur in the underlying Keewatin and some of the more recently discovered ones, near the centre of location R L 404 appear to be in this group. The Keewatin greenstones and other rocks are tougher and do not fracture with the same ease as the overlying series of the Lower Huronian. Hence the solutions have not had the same freedom of movement in the former as in the latter. In so far as the precipitation effects which the rocks of either series may have on solutions working through fissures in them there seems to be little difference between the two. Many of the pebbles and boulders, and much of the cement material in the Lower Huronian have been derived from the underlying Keewatin. Hence one would think they would have about the same influence in precipitating substances from solution as the rocks of the latter formation. The distribution of the Lower Huronian, as will be seen from the map, is irregular. At one time, in all likelihood, it formed a complete layer or mantle over the uneven surface of the older rocks. This has been removed to a considerable extent by erosion, leaving the rocks now in more or less isolated belts and patches.

[5] Over 400 feet of drifting has now been done on this level, and the shaft has been sunk to a greater depth. A winze is sunk, from the level, 100 feet north of the shaft.

The more important veins so far found in the Lower Huronian lie in what may be called three parallel belts. Those first discovered are in a belt which runs about parallel with the railway in the vicinity of Cobalt lake. A small belt connects the northeastern corner of Peterson lake with the northwest corner of Cross lake. A third belt stretches from Giroux lake to the southeast end of Cross lake, in which important deposits occur. Although these three belts have a strike approximately in a northeast and southwest direction, the strike of the veins is not uniform, as will be seen from the plan. Those on J B 7, J B 6, and on the location immediately southwest of the latter claim strike east and west. The veins on J S 14 and J B 1 strike approximately northeast and southwest, while that in the northwest corner of R L 404 strikes northwest and southeast. The vein in the southwest corner of this location strikes east and west, which is the direction of strike of the majority of the veins.

Dimensions

None of the veins are wide. The ore in the Trethewey vein on J B 7, for instance, had a maximum width of about 8 inches, while the vein in the northwest corner of R L 404 has 14 inches of ore, and that on J S 14 showed about 18 inches. Some veins which have been traced 100 feet, or over, average not more than one inch in width (Figs. 1, 6, 9, 10).

The surface, being uneven and more or less covered with loose deposits and with green timber, does not afford an opportunity of tracing the outcrops of the veins any

Fig. 9. A typical silver-cobalt vein on J. B. 6. The head of the hammer shows the width.

great distance, and it is not known definitely how long most of the outcrops would prove to be if the material referred to were removed from the surface of the solid rock.

It is also impossible to give much definite information concerning the depths to which these veins will reach. As already said, most of them do not appear to cut through the older Keewatin series which forms an uneven surface below the Lower Huronian. In the vicinity of Cobalt station the latter rocks are found on hill-tops which stand about 500 feet above the low water level of Temiskaming, where similar outcrops are found. We have reason for saying, therefore, that the Lower Huronian conglomerates and other rocks associated with them may in some places have a thick-

ness of at least 500 feet. In other places this series is entirely wanting, outcrops of the older Keewatin and later diabase forming the surface.

The depth to which a vein may reach depends, therefore, on whether it descends into an old valley of the older rocks or whether it lies above a former hilltop. No one can tell this, of course, without diamond drilling or sinking a shaft. Evidence of the probable thickness of the Huronian or vein-bearing formation can, however, be determined by noting the outcrops of the Keewatin or the intrusive diabases. An exposure of Keewatin surrounded by the Lower Huronian represents an old hilltop. It is therefore evident that a vein which strikes toward this outcrop is likely to have a less depth near the outcrop than some distance away from it. Similarly, if a diabase dike or mass cuts through the Lower Huronian in a vertical direction we have evidence of a greater depth in an adjacent vein than if the diabase cut through the Huronian at a lower angle. In the latter case the vein may be disconnected or cut through by the diabase at no great depth from the surface. Examples of both of these occurrences can be cited in the field. It is likely, however, that in some cases, at least, a vein passing downward through Lower Huronian conglomerate or slate will penetrate sheets or sills of diabase which it may encounter. Similarly veins starting at the surface in a diabase sheet or sill will likely penetrate underlying conglomerate or slate, judging from what we know of the veins of the Port Arthur district, where the diabase bears a similar relation to the fragmental series.

Fig. 10. Vein showing on the wall of a pit at the La Rose mine November, 1904. The width of the vein is equal to the space between the head of the hammer and the man's hand on the handle.

Across the railway track from the La Rose vein, and only a short distance from it, there is an exposure of diabase. This diabase dike, however, shows a vertical face and therefore is seen not to affect the vein. The diabase in some parts of the field has a laccolithic or sill-like structure, overlying the conglomerate and slate, as for example on the western edge of Diabase Mount east of Peterson lake, and on the shores of this

and Cross lake. The relationship is seen to better advantage in the vicinity of Wendigo lake to the northward. The sheet or sill of diabase overlying the conglomerate and slate is of varying thickness.

Distribution of Veins

The veins in the vicinity of Cobalt lake are indicated on the map by the sign —<—— the direction of the line indicating their strike. Some of the veins in the other two small belts which were mentioned above are not thus indicated, as little work was done on them at the time of the writer's visit. They are shown on the plan which accompanies this paper. Smaltite, associated with native bismuth and other minerals, has been found on the north end of lot 15, concession 1, of Bucke, and also on lots not far from the shore of lake Temiskaming in the second concession of this township. These are not shown on the plan. Other promising veins have been discovered, but they have not been examined by the writer.

Ores in Diabase

There are three or four exceptions to the statement that the veins occur in the Lower Huronian. Near the northeast corner of Cross lake, for instance, silver and

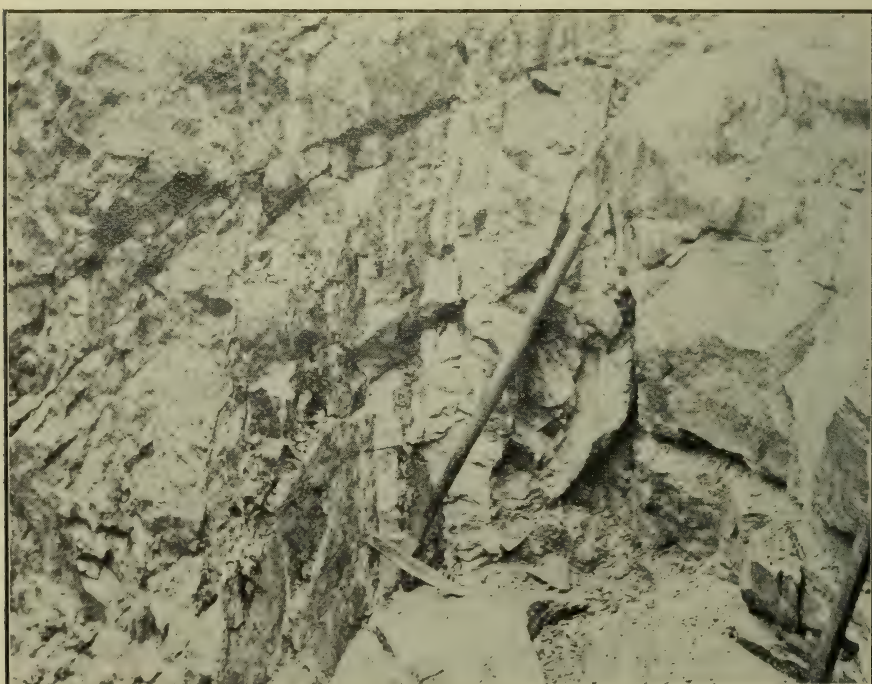


Fig. 11. The hammer is on two veins or branches of a vein on the face of a pit at the La Rose mine, November, 1904.

associated metals are found in diabase along the face of a steep cliff. This diabase mass is, however, overlain in the vicinity by fragmental rocks, Lower Huronian, and it is probable that these originally contained veins which have been worn away, the material in the diabase representing the downward continuation of the veins. On the north end of lot 2 in the third concession of the township of Dymond and on the south end of the lot across the road to the north, cobalt bloom has been found in the diabase. This knoll of diabase is, however, overlain around its base by Lower Huronian rocks, which

have at one time undoubtedly covered the whole of the diabase mass. Here too it is likely that veins at one time occurred in the overlying series which has been removed. Veins were afterwards found in the diabase on the Handy and Jacobs locations in the township of Coleman.

On lots 9 and 10 in the sixth concession of the township of Ingram, 30 miles north of Cobalt station, quartz veinlets in diabase contain bloom and smaltite. Considerable bloom and smaltite have also been found in Keewatin greenstone on the east side of Trout lake and for a mile eastward. This lake lies south of the head of Bay lake on the Montreal river.

Distribution of Ores

A peculiar occurrence of cobalt and nickel with gold was discovered in 1905 on Rabbit lake, east of Temagami and about 30 miles south of Cobalt station. The outcrop is at the water's edge and the deposit has not been uncovered back from the shore. The rocks here have been more disturbed and are much more highly metamorphosed than are those in the vicinity of Cobalt station. They appear, however, to belong to the Lower Huronian conglomerate—greywacké series. The ore body, about 18 inches wide, is in a zone of fracture. Through the chlorite schist which occupies this disturbed zone is a reddish felsitic material, which, under the microscope, is seen to belong to the fragmental series. Veinlets and impregnations of a gray cobalt-nickel ore occur sparingly in both the chloritic and felsitic material. An analysis of some of the more highly mineralized material gave the following results:

	Per cent.
Arsenic	22.53
Cobalt	8.76
Nickel	6.56
Gold	$8.80 a ton.
Silver	1.10 "

This unique deposit is of interest since it shows that cobalt-nickel ores are to be looked for so far south of Cobalt station. The Rabbit lake occurrence is about the same distance south of Cobalt station as those of the township of Ingram are north of it, thus showing that the cobalt-nickel ores are distributed over a distance of at least 60 miles in a north and south direction.

A tract of country 75 miles or more in length, stretching from the vicinity of lake Temagami northward to the height of land and beyond, contains outcrops similar to those which are shown on the map of the area under consideration. As our map shows, the outcrops form a patchwork-like structure. In some part of the area the conglomerate outcrops are much larger than they are in others. In a few of the areas the conglomerate and other members of the Lower Huronian have been practically all removed by erosion, leaving the surface composed of the Keewatin, Laurentian or later diabase. Areas of considerable size are ocupied by the arkose and quartzite of what we have called the Middle Huronian, in which no veins have been found. In any area containing conglomerate and graywacké-slate of the Lower Huronian, it is possible that cobalt-silver veins, similar to those in the vicinity of Cobalt station, may be discovered.

ORES OF THE KEEWATIN

Associated with the greenstones or schists of the much disturbed Keewatin are characteristic ores.

These rocks are found in numerous localities in northern Ontario between the western boundary of Quebec and the eastern boundary of Manitoba. In many places they are iron-bearing, the typical iron formation being composed of interbanded magnetite or hematite with jasper or some other closely related silicious material.

These outcrops of the iron formation, or iron ranges as they are called, have attracted the attention of many writers. Some of the most important of them are the following: those of lake Temagami; that in the township of Hutton; the Michipicoten iron range; and farther west the Mattawin and the Atikokan. In fact, all of the iron ranges of the northern part of the Province, with the exception of those in the Animikie or Upper Huronian series in the vicinity of Port Arthur, and the titaniferous iron ores which are found in a number of places, belong to the Keewatin. There are two or three interesting occurrences in the area under review which show that this Keewatin iron formation has at one time been well developed here. Immediately south of Sharp's Landing, near the shore of Temiskaming, there is an outcrop of the interbanded material which is only about 25 feet in length. No other rocks of the Keewatin are here exposed, the Lower Huronian being distributed over the rest of the surface in the locality. The rocks consist of conglomerate and greywacké slate. The pebbles in these show numerous representatives of the iron formation.

A Buried Iron Range

It is thus seen that we have here a portion of a buried iron range. The strike of the interbanded material in the exposure is somewhat north of west. In the outcrops of conglomerate which are shown on the map in the township of Hudson are found large blocks of this iron formation in the direction from the outcrop at Sharp's Landing represented by the strike of the interbanded material at the Landing. We have thus good evidence that the iron range or formation lies at no great distance from the surface in this part of Hudson. Between these outcrops of conglomerate and Sharp's Landing the range is cut through by diabase and it is overlain by Niagara limestone and recent clay deposits in addition to the Lower Huronian. This iron range no doubt extends farther west than Hudson. It has been covered up since Lower Huronian times, as shown by the fact that it is overlain by rocks of this series, and has therefore not been subjected to glaciation, which is supposed to have produced injurious effects on the iron deposits of Ontario, it having been held by some writers, for instance, that the soft ores in these deposits have been gouged out and carried to the southward. Near the southwest corner of Cross lake in the township of Coleman there is a small exposure on the shore which also carries large angular blocks of the iron formation. There is, in all probability, a portion of a buried iron range in this vicinity. Much of the conglomerate in various parts of the area contains jasper pebbles and other material derived from the iron formation.

In addition to the iron ranges which are found in the vicinity of lake Temagami, 25 miles to the south of Cobalt, there are outcrops of similar material in the township of Boston to the northward. The outcrops in this township are described in a paper in part I of this report.

Iron Pyrites

The iron pyrites deposits of this part of Ontario also belong to the Keewatin. One of these is shown on the map near the Montreal river, south of the township of Coleman. Others have been worked still farther to the southward between this point and lake Temagami. Copper pyrites has attracted attention at numerous places in this series, but, so far as the writer knows, no large deposits of this mineral have as yet been found.

Arsenic

Near the railway track, a short distance north of lake Temagami, two deposits of auriferous mispickel are being worked in the Keewatin. These are known as the "Big Dan" and "Little Dan" prospects, respectively. Mispickel is the sulph-arsenide of iron. It seems strange that it should be gold-bearing while 25 miles to the north the arsenides of the metals cobalt and nickel, which are closely related to iron, are silver bearing. Arsenic occurs, therefore, in this district in considerable abundance. The

rule derived from the deposits already worked is that the ores of this metal in the Keewatin are gold-bearing, while those in the overlying Lower Huronian are silver-bearing. Why this should be the case is difficult to explain. It may also be added that the pyrite, especially in the vicinity of lake Temagami, practically always carries some gold, frequently from one to two dollars per ton. Gold has, however, been found in Lower Huronian ore. That of the Benn mine, lot 15 in the first concession of Bucke, showed $5.20 to the ton in one sample, the ore being cobaltite, a compound related to mispickel, and that from Rabbit lake is also gold-bearing. The presence of a sulph-arsenide, either mispickel or cobaltite, in an ore from this district is an indication that the ore carries more or less gold.

Fig. 12. Trethewey vein and discovery post, J B 7, May, 1904.

The ores of Temagami and Cobalt station, both being rich in arsenic, would seem to warrant the eretcion of an arsenic refining plant somewhere along the railroad between these two points. In so far as the writer knows, there is not another site as promising for a plant of this character in North America. Water power is available.

Arsenic is marketed in the form known as 'White arsenic," As_2O_3. This oxide is produced by roasting various minerals containing the metal. These minerals contain a much lower percentage of arsenic than do ores from most of the Temiskaming cobalt-silver deposits.

Up to a few years ago the only arsenic plant in North America was that at Deloro, Hastings county, Ontario. Here the ore is a gold-bearing mispickel, similar to that of Temagami. More recently an arsenic plant has been erected in the state of Washington and another in Virginia. The production of these plants is not large.

White arsenic contains theoretically 75.8 per cent. of arsenic and 24.2 of oxygen. One pound of arsenic in an ore, if roasted, will therefore produce, theoretically, about one and one-quarter pounds of white arsenic.

During recent years white arsenic has been worth about $60.00 a ton or three cents a pound. In the year 1903 the United States imported $256,097 worth of white arsenic, metallic arsenic and arsenic sulphide. White aresnic was quoted at over $100 a ton in the beginning of 1906.

The greater part of the white arsenic produced at the Deloro works was consumed in the plate glass industry of the United States. It is said that if the glass manufacturers were assured of a constant supply at satisfactory prices they would use white arsenic in place of the oxide of antimony, which they commonly employ as an oxidizer.

Other uses of white arsenic are in Paris green and various paints, in sheep dips, insecticides, aniline dye works, etc.

An instructive paper, by Mr. J. Walter Wells, on the manufacture and uses of arsenical compounds is published in the Eleventh Report of this Bureau, pages 101 to 122. Papers by Messrs. Kirkegaard and Wright are to be found in the transactions of the Canadian Mining Institute, vol. 2, 1897, and vol. 4, 1901-2.

An arsenic plant for treating the ores from Cobalt is now in operation at Copper Cliff, Ont.

LIMESTONE

It will be seen from the map that the Niagara limestone froms some large outcrops on the islands and in the vicinity of the shore near the northwest corner of lake Temiskaming. This limestone affords stone suitable for building and for the production of lime, and on this account should be of considerable value in the years to come, since limestone is a somewhat rare material in most of this northern part of Ontario. The district to the west and north is being rapidly settled and will soon contain a large population which will need much material for building purposes. The following is an analysis of a sample of limestone taken from Farr's quarry, Haileybury:—

	Per cent.
Insoluble residue	1.60
Ferric oxide and alumina	.66
Lime	29.50
Magnesia	21.59
Carbon dioxide	46.84
Sulphur trioxide	.70
	100.89

This limestone formation extends northward, although overlain by clay and similar deposits in many places, and has been observed by the writer along the south branch of the Blanche river below what is known as the Mountain portage.

Considerable attention has been paid to the limestone area, Sir William Logan having first described it years ago. It has been shown that the series here is more closely related to the Niagara of Southern Ontario than it is to the Niagara areas to the north and west.

CLAY

A couple of miles northward of Cobalt station the agricultural region of this part of northern Ontario is met with. The soil is essentially a well banded clay (Figs. 13, 14). Between this point and the height of land, or watershed, between the Hudson Bay and Ottawa river waters, the clay does not form a continuous mantle, but there are large areas of tillable land which is being rapidly settled. Outcrops of solid rock, in many cases representing hill tops which project through the clays, are seen. North of the height of land, however, is a large agricultural area, estimated at 16,000,000 acres, and

known as the "great clay belt," in which exposures of solid rock are few in number. The clay on both sides of the height of land is pretty uniform in character. Following is an analysis of the clay in a cut on the railway between Haileybury and New Liskeard. It will be seen that the lime and magnesia are rather high. This is owing to alternate bands containing considerable marl. The clay effervesces strongly in acid.

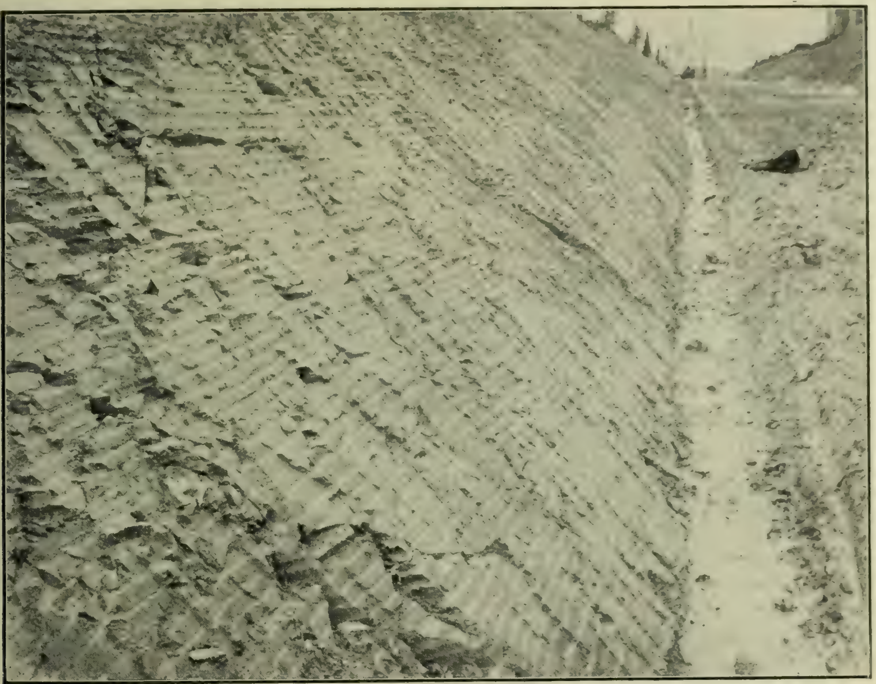


Fig. 13. Bedded clay in railway cut between Haileybury and New Liskeard.

	Per cent.
Silica	52.00
Alumina	16.11
Ferric oxide	4.69
Lime	8.26
Magnesia	4.10
Potash	1.74
Soda	2.76
Sulphur trioxide	.09
Loss on ignition	9.64
Total	99.39

REGIONAL DISTURBANCES

From the geological map and the plan, showing the distribution of the veins, which accompany this report, it will be seen that the area so far productive can be covered by a rectangle with a length of two miles and a half in a north and south direction and a width, east and west, somewhat less.[5] The chief producing properties in the northwestern part of this rectangle surround cobalt lake and the railway. The other important group lies immediately south of Glen and Kerr lakes in the southeast of the rectangle. It will be seen that while the belts of the fragmentary rocks, of what we have called

[5] Native silver has since been found, in a north and south direction, over a distance of about six miles.

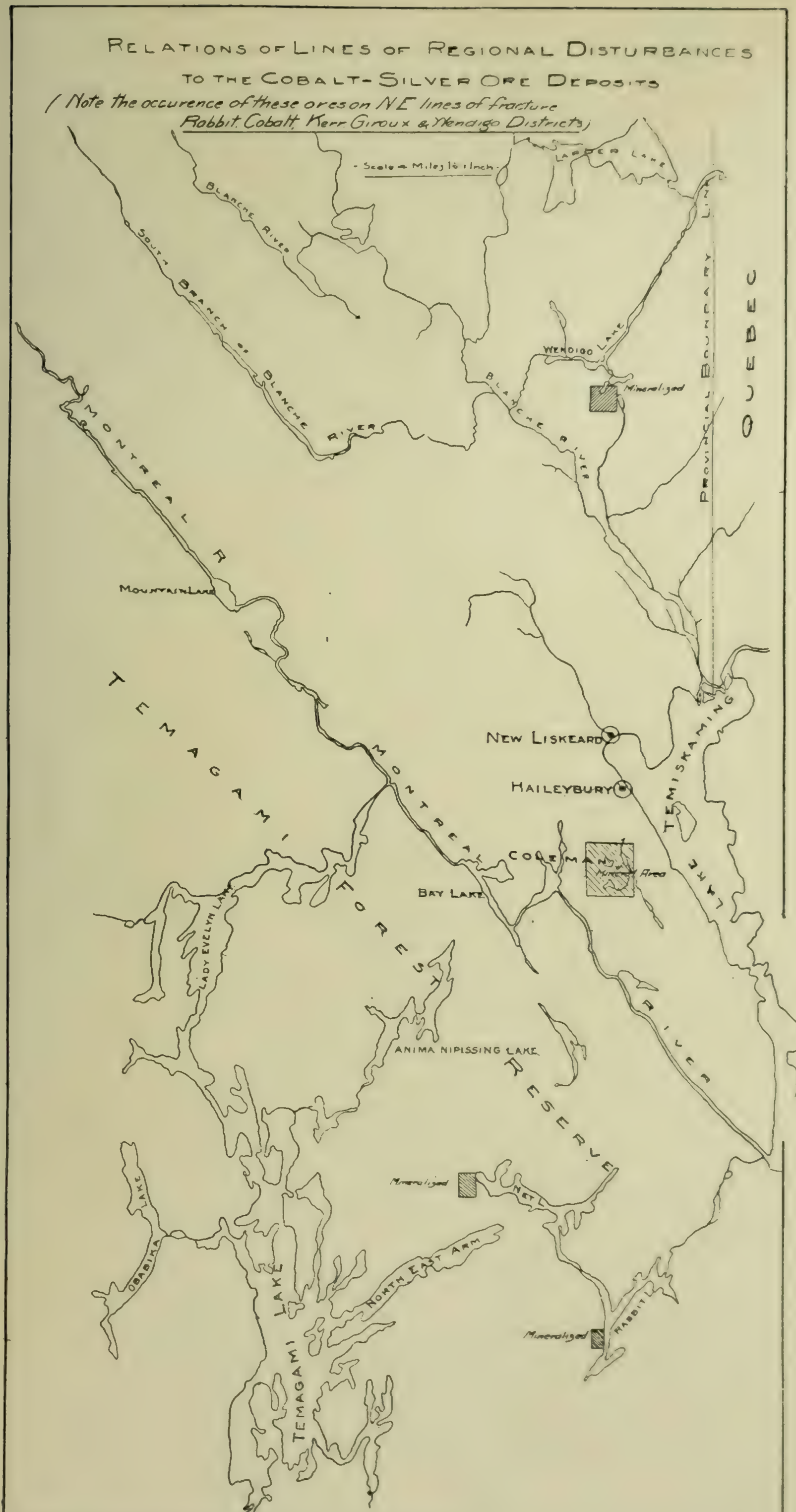
the Lower Huronian, strike approximately northeast and southwest, as for example the Glen and Kerr lake belt, the majority of the veins have a strike different from this. It would also appear that the strike of the veins in this area has little connection with the disturbance or disturbances which caused the great majority of the larger rivers and chains of lakes in the district to follow one or other of two well defined directions.

A glance at a general map, such as the "Map of Part of the District of Nipissing," published by the Department of Lands and Mines of Ontario, will convince the reader that the system of water courses in the district is a truly remarkable one (Fig. 15). The Nipissing and Temiskaming map sheets published by the Geological Survey, Ottawa, show the system to hold over a still larger district. The chief water courses, as the maps show, follow either a northeast and southwest, or a northwest and southeast direction. While both of these courses are indicated clearly on the maps, the latter is the more prominent.

Fig. 14. A part of the face of the cut shown in Fig. 9 enlarged.

N.W.—S.E. Water System

The Temiskaming and Northern Ontario Railway, recently completed to the head of lake Temiskaming from North Bay junction, on the main line of the Canadian Pacific railway, has naturally been constructed along the line of least resistance, or in other words, it has been built for the most part along a line of depression in order to avoid costly rock cuts. The map shows that this road practically parallels, running in a northwesterly direction, the Ottawa river and lake Temiskaming for the first 90 miles or more of its course, to the crossing of the Montreal river at Latchford station, the railway being 15 or 20 miles to the westward of the Ottawa. At Latchford the railway turns northeastward and runs for 12 or 14 miles, parallel with the second great system of water courses, to Haileybury on lake Temiskaming. The direction followed by the railway for the first 90 miles of its course proves that there is a line of depression here, parallel



RELATIONS OF LINES OF REGIONAL DISTURBANCES
TO THE COBALT-SILVER ORE DEPOSITS
(Note the occurence of these ores on NE lines of fracture
Rabbit, Cobalt, Kerr, Giroux & Wendigo Districts)
Scale 4 Miles to 1 Inch
LARDER LAKE
BLANCHE RIVER
SOUTH BRANCH OF BLANCHE RIVER
WENDIGO LAKE
Mineralized
BLANCHE RIVER
PROVINCIAL BOUNDARY LINE
QUEBEC
MONTREAL R
MOUNTAIN LAKE
TEMAGAMI FOREST RESERVE
NEW LISKEARD
HAILEYBURY
TEMISKAMING
MONTREAL
COLEMAN
Mineral Area
BAY LAKE
LAKE
LADY EVELYN LAKE
RIVER
ANIMA NIPISSING LAKE
Mineralized
NETL
OBABIKA LAKE
NORTH EAST ARM
TEMAGAMI LAKE
Mineralized
RABBIT

Fig. 15.

with the Ottawa river and lake Temiskaming although it is not indicated by water courses on the map along the greater part of the route.

Continuing northwestward from Wabi bay, the northwest corner of lake Temiskaming, and in line with the direction followed by the main body of this lake and the Ottawa river for about 75 miles, there is a water course. Wabi creek, which flows southeast for about 15 miles. In line northwestward from this point on Wabi creek the map of Nipissing does not show any prominent water course in a direction northwest and southeast for about 15 miles, although two branches of the Blanche river cross this space on the map in a direction northeast and southwest, parallel with the other great system of water courses. Ffteen miles in line northwestward of that part of Wabi creek referred to, the lake Temiskaming-Ottawa river line is continued northwestward by what is here known as the south branch of the Blanche river. For 15 miles northwestward here the river is represented by lake expanses, Long and Kenogami lakes, and for 15 miles above the upper of these lakes, the river is ascended in a northwest direction to the limits of the map of Nipissing, to which reference has been made.

The length of the line followed northwestward from Mattawa by the series of water courses mentioned—Ottawa river, lake Temiskaming, Wabi creek, Long and Kenogami lakes and the upper part of the south branch of the Blanche river—is approximately 135 miles.

It will be seen, however, that there is a bend in lake Temiskaming near the point where the Montreal river enters it. The lower part of the lake and Ottawa river are therefore more in line with the Montreal river than with Wabi creek.

The Blanche river enters the northeastern expansion of lake Temiskaming and the main stream and Round lake branch of this river follow a northwest line for a distance of 35 or 40 miles. This northwest axis of the Blanche lies parallel with the Wabi creek-lake Temiskaming axis, and 9 or 10 miles to the northeast of it.

A third water course which shows a striking parallelism to the two described is that of the Montreal river, which lies 10 or 11 miles southwest of the northwest axis of the Ottawa river. From the railway crossing at Latchford station northwestward through Bay lake and the townships of Auld, Barber, James, to the edge of the Nipissing map, the line of the river holds its northwestward course for over 50 miles. Southeastward from Latchford station the line of weakness, if we can so call it, is continued through Straight, Johnny and Rib lakes for 9 or 10 miles. It will be seen that in the township of Barber and immediately below Latchford station, for example, the river changes its course for 3 or 4 miles, here following the direction of the other great system of water courses, that is the northeast and southwest one, but it gets back again into its normal northwest and southeast course.

Immediately east of the Cobalt-Silver area there is a chain of small lakes—Cross Kirk, Chown and Goodwin—with connecting streams, which follows a clearly defined northwest and southeast direction, parallel with the shore of Temiskaming, distant 3 miles to the eastward.

N.E.—S.W. System

The water courses and lake axes which lie in a northeast and southwest line are not so prominent on the map as are the northwest-southeast ones just described; still they form a not indistinct system, and, as indicated by fig. 15, they seem to have an important, but as yet little understood, relationship to the cobalt deposits of not only Cobalt proper but of those of Rabbit lake 30 miles to the south and of Wendigo lake 30 miles to the north. If a line be drawn on the map from near the mouth of the Quinze river, at the northeast extremity of lake Temiskaming, southwestward to Latchford station on the Montreal river, a distance of 22 or 23 miles, and beyond, it will be seen that it follows the main axis of the large northeast bay of lake Temiskaming, and that the longer axis of Cobalt lake lies parallel to it. Several other small lakes—Short, Pickerel and Bass—lie approximately on this line, as does also that part

of the Montreal river between Latchford station and the Sandy portage. Farther southward it will be seen that one long narrow arm of lake Temagami and adjacent bodies of water follow a northeast and southwest line for over 20 miles. Rabbit lake, east of Temagami, has one arm 5 or 6 miles in length running in the same direction and another whose axis follows a northwest-southeast line. The two arms of Obabika lake, to the west of Temagami, show a similar relationship, one to the other.

The most striking water course following a northeast-southwest line is, however, the northeast or what is sometimes called the Abitibi branch of the Blanche river. There is a string of eleven lakes here between Windigo lake, north of the township of Ingram, and the Quebec boundary, a distance of 15 miles. To the southwestward in the townships of Armstrong and Henwood the south branch of the Blanche follows about the same direction. Otter and Wright creeks which run from the Quebec boundary into the Blanche river, between the head of Temiskaming and Tomstown, flow in a southwest direction.

At points where the two systems of water courses join a number of striking V-like turns are shown in lakes and rivers, as for example, those formed by (1) the two arms of Rabbit lake, (2) the northeast arm of Temagami with the main body of the lake, (3) the turns in the Montreal river at Latchford station and at the Sandy portage, (4) the longer axis of Wabi bay with that of Paulson's bay at the head of lake Temiskaming. The angles thus formed appear to be slightly less than a right angle and the V in all but one of the cases mentioned points southward. The axes of the two arms of Obabika lake form an angle greater than a right angle, which points eastward.

Considering the great variety of rocks cut through by the water courses of the two systems, the regularity of their courses over such a large district is remarkable. A few lakes and streams have their longer axis lying in a north and south or in an east and west direction, but they do not form a system comparable to either of the other two.

Origin of the Systems

Concerning the origin of the two great systems of water courses little can be said at present. It is impossible to say whether the courses follow fault lines or simply folds. They are doubtless due to regional disturbance in post-Middle Huronian times. Much of the surface of the country is covered by recent and glacial deposits, and the rocks where exposed present such a complex of igneous and metamorphosed fragmental material, with minor faults and folds, that it will be difficult to prove the existence of what may be called regional faults or folds.

At Cobalt lake, which has its longer axis parallel with one of these regional axes, if we may so call them, the beds of the Lower Huronian greywacké-slate and conglomerate dip towards the lake, as shown at the veins on location J B 6 and on Cobalt hill, location R L 404. The lake, judging from the dip of these rocks, occupies the axis of a syncline. The hills where the dip was observed lie at an elevation, on both locations, of about 100 feet above the railway track at Cobalt station. At the powder house vein, however, on location J S 14, near the foot of Cobalt lake, the slate is seen to be practically horizontal. The vein here referred to is at the base of a cliff, which rises to a height similar to that of the hills across the railway track to the westward on the southern part of R L 400. In the former case, the hill is composed entirely of the greywacké-slate, while on R L 400 the rock is conglomerate of the same series. It would thus appear that the railway here follows approximately a line of fault, especially as the main shaft on J S 14 penetrates conglomerate, similar to that in the hills on R L 400, at a depth from the surface of 80 feet. There may thus, be a fault here parallel with the main axis of the synclinal fold and Cobalt lake. The strike of the main vein of the La Rose mine, J S 14, near the foot of Cobalt lake and that of the McKinley and Darragh vein at the head of the lake are approximately parallel with the main axis of the lake. The outcrop of diabase across the railway track opposite

the La Rose vein appears to be in the form of a dike, as does also the diabase near the McKinley and Darragh vein. These diabase outcrops seem to indicate a line of weakness parallel with the lake and the railway.

CHARACTER AND STRIKE OF VEINS

The accompanying plan of the veins, prepared by Mr. W. A. Begg, shows that the strike of few of them conforms to the directions or lines of weakness followed by either of the two great systems of water courses, which have been described. It would appear that there is more uniformity in strike among the veins which lie to the westward of Cobalt lake than in any other part of the area. The vein on which the Trethewey mine is situated has a strike of about N. 85° W. A narrow stringer immediately north of this has a similar strike, as have also the seven veins on J B 6. On the Denison location, immediately southwest of J B 6, two narrow veins have a strike similar to

Fig 16. Columnar jointing perpendicular to the planes of bedding in greywacké-slate. The structure is due to the effects of intrusive diabase on the slate. A section of a small column is on top of the larger one. Lot 15 in the first concession of Bucke.

that mentioned, as has also the vein worked on the claim to the southwest of Denison's The strike of these veins, on J B 6 at least, is parallel with the dip of the enclosing rocks. The dip can be determined here in but few places. On J B 6 at one point it was seen to be about 20° to the eastward. (*See* Sketch Map, page 10).

"It is not always possible, in a shattered rock, to discriminate between joints and those lines of division to which the term fissure is more usually restricted. Many so called fissures may be merely enlarged joints."[6] This holds true in the cobalt-silver area. While the openings occupied by some veins, or part of a vein, can be called fissures. there are many more to which the writer is inclined to apply the term joint. The openings in the greywacké and conglomerate are in many cases connected with columnar

[6] Geikie, Text Book of Geology, p. 688.

jointing in these rocks. A vein may occupy a distinct fissure-like opening for some distance, then it may split up, the stringers thus formed running around columns out of the former course of the vein and coming back some feet ahead into the line first followed. The columnar jointing is well shown in the rock cut along the railway a short distance south of Cobalt station. Several of the trenches, 20 feet or more in depth, from which ore has been extracted, illustrate the same phenomenon.

The well banded greywacké-slate on the north part of lot 15 in the first concession of Bucke, has this columnar structure very perfectly developed in it (Fig. 11). The columns here have a much smaller diameter than those just mentioned. They are developed at right angles to the bedding of the slate which is almost flat-lying, and they are nearly as perfect in form as those sometimes found in basalt. On this lot in Bucke the columns are developed at the contact of the slate with intrusive diabase. That columnar structure of this kind is not uncommon in fragmental rocks is seen from the following statement: "Contact with eruptive rocks has frequently produced a prismatic structure in the contiguous masses. Conspicuous illustrations of this change are displayed in sandstones through which dykes have risen. Independently of the lines of stratification, polygonal prisms, six inches or more in diameter, and several feet in length, starting from the face of the dyke, have been developed in the sandstone."[7]

Whether we call the openings occupied by the cobalt-silver veins and stringers fissures or joints, it seems likely that they have been produced by the diabase which intruded the Lower Huronian rocks in which the veins are found. The diabase formed sheets or sills, in many cases, which appear to have had a great horizontal expansion. Owing to denudation, diabase outliers are now found at many points overlying the older fragmental rocks. The sills here appear to be comparable with those in the vicinity of Port Arthur, on the north shore of Lake Superior. As previously shown, a few cobalt-silver veins have been found in the diabase. Silver veins in the Port Arthur area also cut both the Huronian and diabase, many of them passing from one rock into the other (Fig. 17).

METAMORPHISM OF SILVER AREA

As already shown, there is a similar assemblage of rocks, to that surrounding Cobalt station, over an area which is at least 75 miles in length from north to south. The question then arises as to why deposits as rich in silver as those near Cobalt have not been found here and there all over this large area. The only answer to this question which the writer can give at the present time is that the rocks in the vicinity of Cobalt station appear to have been less disturbed and less highly metamorphosed by the regional disturbances than have those in the surrounding areas. For instance, while much of the Lower Huronian in the productive area lies in horizontal beds or in those which dip at a low angle, similar rocks a few miles north, near Sharp's Landing, dip at angles of 60° or more. In the vicinity of Temagami and Rabbit lakes to the southward similar rocks have been rendered schistose. South of Wendigo lake, 30 miles to the north of Cobalt station, the conglomerate and greywacké-slate, while frequently lying almost horizontally, appear to have been baked and hardened much more than those in the productive area. Quartz stringers appear to be characteristic of the more disturbed areas.

It would appear then that the rocks in the productive area had escaped the greater disturbances and metamorphism to which those in surrounding areas have been subjected. This left them in the right physical condition to be readily jointed and fissured by the contraction of the diabase. After the deposition of the cobalt-nickel arsenides, which seem to be among the first minerals deposited, the veins appear to have been slightly disturbed, giving rise to cracks and openings in which the silver and later minerals were deposited. Veins which escaped this later, slight disturbance contain little or no silver.

[7] Geikie, Text-Book of Geology, p. 769.

There may be other differences between the productive area and those which surround it. Intrusions of rocks later in age than the diabase and gabbro may have played some part in the formation of the ores. Only one such intrusion has been observed in the field. This is the Cross lake basalt, referred to on another page. It is very difficult, in most cases, to distinguish these basic rocks of different periods of eruption. Keewatin diabases may be mistaken for those of later age, and *vice versa*.

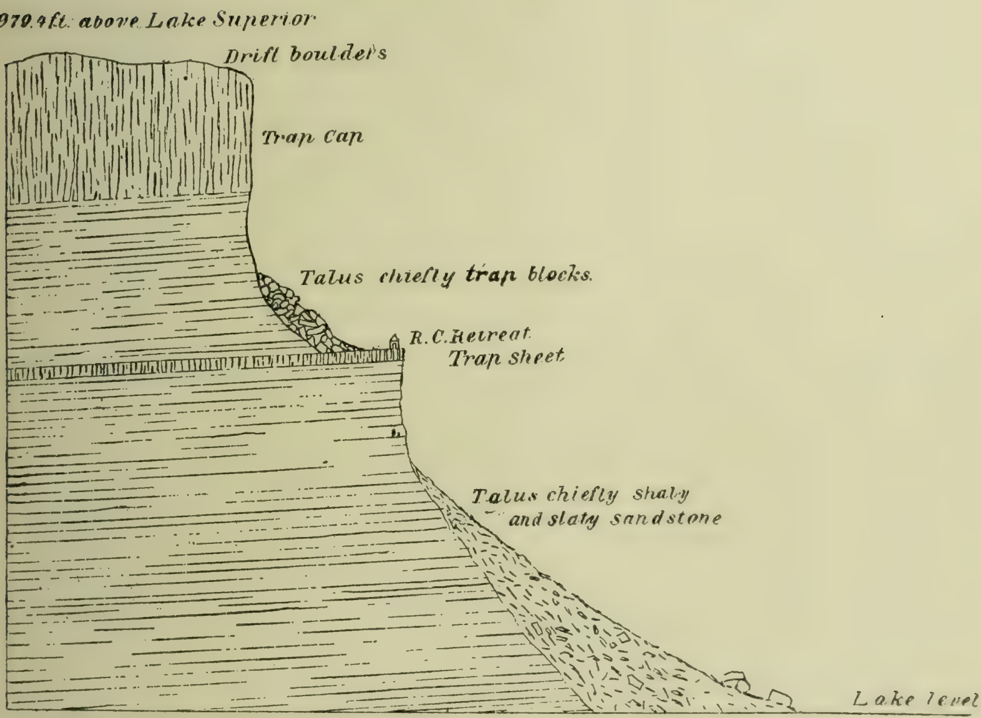


Fig. 17. Section through Mt. McKay near Fort William, Ont. The trap here bears a similar relationship to the slaty series to that which it has in the Cobalt area. Some silver veins in the Port Arthur area cut both the trap and slate. (After Dr. A. C. Lawson.)

THE ROCKS OF THE AREA

Owing to the fact that the surface is covered with green timber and there is much drift material, contacts and good exposures are difficult to find in places. Facilities for mapping will be much better in a couple of years, as mining progresses and the timber is removed.

From the colored map which accompanies this Report it will be seen that there is a considerable variety in the pre-Cambrian series. The Niagara of the Silurian system also shows prominent outcrops. Between the Niagara and the Pleistocene or glacial there are no formations represented in the district. The pre-Cambrian has been separ-

ated into the following series by the writer. It is possible, however, that unconformities exist which have not been located as yet. It may be said that there is some indication of an older, unclassified fragmental or Huronian series in the district. If this can be isolated our Lower will become Middle, and our Middle will be classified as Upper Huronian.

In mapping the area I had the valuable assistance of Messrs. Cyril W. Knight and R. Anson-Cartwright. The mapping of some parts of the field is entirely the work of these gentlemen.

Keewatin and Laurentian: The oldest series in the district consists of an igneous complex which contains diabases, and related rocks of different periods of eruption, together with granite-porphyry and other igneous material. Sediments are represented by the jasper-iron ores. The basic rocks or greenstones occur in much larger volume than do those of a more acid character. The name Keewatin is applied to this series. It has been subjected to folding and other disturbances, and is cut through by medium to coarse-grained granite, especially in the township of Lorrain, to which the name Laurentian is applied. The Keewatin rocks, however, have been folded before the intrusion of the Laurentian.

Huronian: After the Laurentian intrusion the surface was subjected to erosion, and these rocks, together with the Keewatin, were worn down. This period of erosion was a long one, and the surface was rendered very uneven, being cut into hills and valleys somewhat like those of the present surface. The oldest fragmental material which lies directly on the eroded Keewatin and Laurentian surface consists of conglomerates, greywacké-slate and impure quartzites. These rocks contain fragments of the granite, greenstone and other representatives of the older series, and their relationship to the latter is quite easily proved by contacts in a number of localities. This older, or, as it is called on the map, Lower Huronian, is of special interest since it contains most of the cobalt-silver veins.

The association of the members of the Lower Huronian is somewhat variable. There is usually a little coarser material, conglomerate, at ths base. This is frequently followed by a considerable thickness of well banded greywacké-slate. The slate in many cases passes gradually upwards into a feldspathic or impure quartzite which is succeeded by a coarse conglomerate. The greater part of the conglomerate is undoubtedly younger than the more slaty members. The relationship of these members of the Lower Huronian is well seen in the Little Silver vein cliff in the southwest corner of R L 404 (Frontispiece).

The veins cut through all these series, but the most productive parts of the veins are usually in the rocks which contain more or less coarse fragments. It is believed that the fissures now occupied by these veins were produced at the time of the eruption of the younger diabases and gabbros which will be referred to again.

This Lower Huronian series has at one time had a greater thickness than it has at present. Being laid down on an uneven surface, it is impossible to say what the thickness of the series is at any one point; it may be a few feet or it may be a few hundred feet. In some places it is entirely absent, the older series or floor on which the Lower Huronian is laid being exposed at the surface. The hills near Cobalt station, however, where these conglomerates and other members of the series outcrop, are 500 feet above the water level at the shore of lake Temiskaming, where similar outcrops are found. It would thus seem that the Lower Huronian may in some cases have a thickness of at least 500 feet.

Middle Huronian: The series of arkoses, or what have been called by some writers sea-green quartzites, together with conglomerates and quartzites of the township of Lorrain, form another series in the Huronian, the present writer having found that they are unconformable to the Lower Huronian. This series in the eastern part of the area has been derived chiefly from the erosion of the Lorrain granite, and much of the area, between Chown and Goodwin lakes on the west and Paradis bay on the east, con-

tains small patches and outliers of this series. It is impossible to represent these on the map, the passage from granite into the decomposition products being so gradual. On lot 4, in the twelfth concession of Lorrain, a striking contact between the Lower Huronian and Middle Huronian is seen, fragments of slate of the former being cemented in the arkose of the latter. Fig. 22 shows a specimen from this contact.

On the eastern shore of Temiskaming the two series, so far as seen, appear to be conformable.[8]

There is no reason so far as the writer knows, why this Middle Huronian should not contain veins as well as the Lower Huronians since it is also cut by the diabase and has been subjected to similar disturbances. The intrusive nature of the diabase as regards the Middle Huronian is seen on the shore of Temiskaming just south of Devil's rock.

Diabase and Gabbro: It will be seen from the map that these rocks occupy a considerable part of the surface of the area under review. In most cases, where associated with the Huronian, they seem to be in the form of sheets or sills spreading between or over the layers of the rocks through which they cut. They show no evidence, such as amygdaloidal texture, of being surface flows. These rocks are much fresher in appearance and coarser in grain than those of a similar composition which occur in the Keewatin, and can thus usually be readily distinguished in the field from the latter. After the eruption of these diabases and gabbros, whose exact age is not known, that is, whether they belong to the Upper Huronian or the Keewenawan, erosion of the surface again took place for a long period of time, and all the series now exposed in the field, with the exception of the younger Niagara, were worn down.

Diabases representing several periods of eruption, Keewatin to post-Middle Huronian, are found and it is very difficult to distinguish them in the field. On the south shore of Cross lake the diabase which contained cobalt-silver veins is cut by a younger basalt.

Niagara: This Silurian series consists of similar rocks and fossils to those which are found in the districts to the south. It is composed essentally of limestones which contain a little conglomerate and sandstone at their base. The region has been subjected to little disturbance since the deposition of these Niagara rocks.

Glacial and Recent: Much of the surface of the area covered by the map is occupied

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[8] Sir William Logan (then Mr. Logan) explored Lake Temiskaming in 1845-6. The account of his trip, published in the report of the Geological Survey for those years, pages 60-70, is of interest.

"Ascending Lake Temiscamang, the slates come in upon the gneiss about three miles below the mouths of the Montreal and Metabecchuan Rivers, on the west bank, and about three miles above them on the east: and they occupy both sides to within two and a half miles of the Hudson Bay Company's Post. In this distance they may have a direct breadth of about seven miles in which they are effected by at least one undulation, and probably more, and constitute hills of 300 or 400 feet. As gathered from the map of D. Taylor's exploratory journey from Lake Huron to the Ottawa by Lakes Nipissing, Temagamang and Temiscamang, the slates in a westerly direction run forty miles in a line about S. 40° W., from the latter Lake to Bass Lake, on the Sturgeon River, which discharges into Lake Nipissing on the north side, and it appears probable they will come upon some part of the north shore of Lake Huron. On Lake Temiscamang they are followyd by the sandstones, which cross the lake with a strike of N. 60° E., and dipping northward at a very small angle, after having been piled up into a range of about the same elevation as the slate hills, they reach the Company's Post, where, nearly flat, they run under a narrow gravel hill, 130 feet in height; emerging beyond, they continue to a distance of about half a mile above the Post, and there become interrupted on both sides of the lake by a mass of syenite. This syenite does not possess the gneissoid arrangement of the rock lower down the river, but it appears to be nearly similar in other respects, being composed of reddish feldspar, white or colorless quartz, and a sparing quantity of green hornblende. The breadth of this syenite band is pretty nearly three miles on both sides of the lake. On the west it is succeeded by the sandstones, which run along the coast for a distance of four miles, nearly in the strike of the measures, dipping towards the water at a small angle, and are followed by the slates, which come from behind them, and continue in a straight line for nine miles to the western bay at the head of the Lake, forming high, perpendicular cliffs for part of the way, and rounded hills for the remainder. On the east side, the syenite gives place to the slates, which there present the porphyritic appearance already mentioned. The sandstones come upon them on tne south side of the southern large island, and the mainland near, dipping a little to the west of north at an angle of three degrees: and both they and the slates, with their associated conglomerates, make their appearance at occasional points along the coast, wherever denuded of the overlaying limestones, the basset edge of which thinly covers them, to the island at the entrance of the eastern or Moose Bay. Beyond this the sandstones, gently dipping south, are seen in a projecting point to the east of the island. The slates are met with at the mouth, and at the first, second and third Portages, of the Riviere des Quinze, or Moose River and their associated conglomerates in the bay to the west of the Blanche.

"The limestones constitute the two large islands north of the Company's Post, the two smaller ones between them, the island already mentioned planted at the entrance of the eastern bay, and a very small one on the west coast, as well as the promontory which separates the east bay from the west. The strata lie in the form of a shallow traugh, based sometimes on the sandstones and sometimes on the slates, accupying the breadth of the lake,—from five to six miles—and extending from the south side of the southern great island to some unknown distance northward, being probably a projecting point or an outlier of some more extended calcareous area nearer Hudson's Bay."

by boulder clay and loose bedded deposits. The distribution of these materials has not been shown on the map, owing to the fact that their mapping would have taken more time than we had at our disposal.

Keewatin

The folding which has been produced in the Keewatin is well shown by the torsion cracks in Figs. 18, 19. The photographs which these represent were taken at the contact of the Keewatin with the Lower Huronian, at the shore of Temiskaming, on lot 15 in the second concession of the township of Bucke. This contact is shown on the map. It is an important one owing to the fact that it is easily reached from the town of Haileybury, either by water or by land. The Keewatin greenstone also frequently shows spheroidal parting similar to that which has been described in the Vermilion district of Minnesota.

Mr. M. B. Baker who examined, microscopically, specimens of the Keewatin greenstone from near the contact on the lot above mentioned says that the rock has a very fine grained trap-like appearance. The two important constituents are green horn-

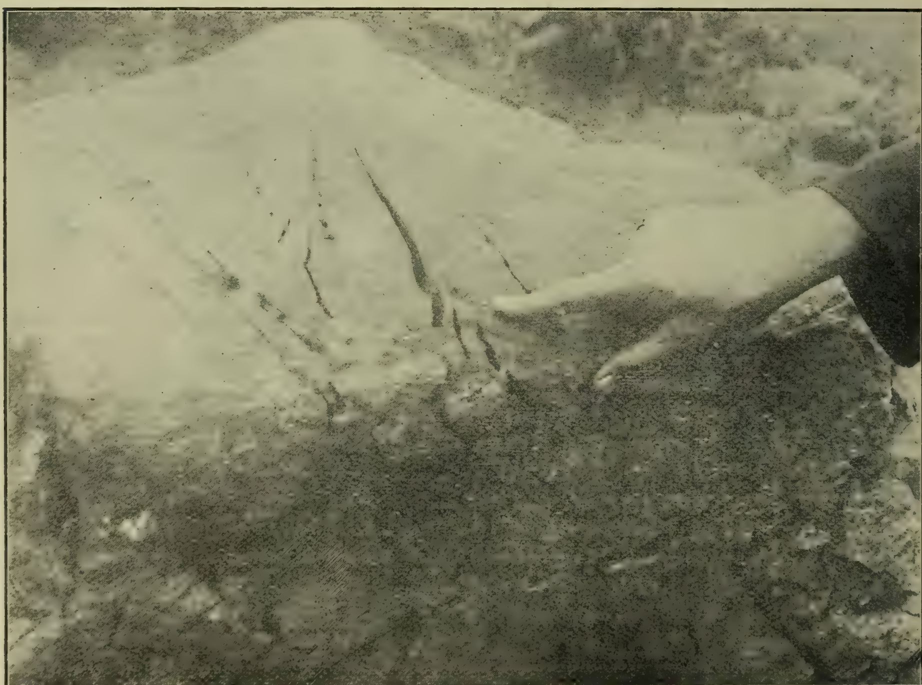


Fig. 18. Torsion cracks in Keewatin greenstone. Lot 15 in the second concession of Bucke.

blende and plagioclase. The former mineral occurs in angular grains and blade-like pieces, which show a frayed structure, and is altered to chlorite. Much of the plagioclase is changed to kaolin and occurs in lath-like forms. Some sections show a well defined ophitic structure, so that the rock can now be called a fine-grained hornblende diabase. Other specimens of the Keewatin greenstone examined by the writer from the railway cuts near Pickerel lake and elsewhere are similar in character.

At the immediate point of junction or contact of the Lower Huronian with the Keewatin on the lot to which reference has been made, the greenstone of the latter is cut through by a dike of porphyry of pre-Huronian age. This porphyry shows similar cracks to those presented by the Keewatin, but its porphyritic texture serves as a good means of identification. It frequently is difficult to distinguish the more

or less metamorphosed greenstones of the Keewatin from some of the slaty-greywacké phases of the overlying Lower Huronian. These greywackés are simply the recomposed greenstones, or in other words after the greenstones have broken down into fine material this has been resolidified into slate-like rocks. But at the contact referred to we find pebbles and boulders of the Keewatin porphyry dike in the overlying Huronian, and there is no mistaking these pebbles and angular fragments for something else. (Figs. 20, 21). In many other outcrops one has not his attention drawn to the unconformity at once. There is a well defined contact in a light colored knoll which lies some distance east of Farr creek on the northeast corner of lot 13 in the first concession of Bucke. This hill is in the bush but can be seen on looking southward from the road. Northward from the road here there are also contacts. The location of these is shown on the map.

Previous maps of this district have shown as one series the Keewatin, Lower Huronian and Middle Huronian, thus bringing out the fact already illustrated that

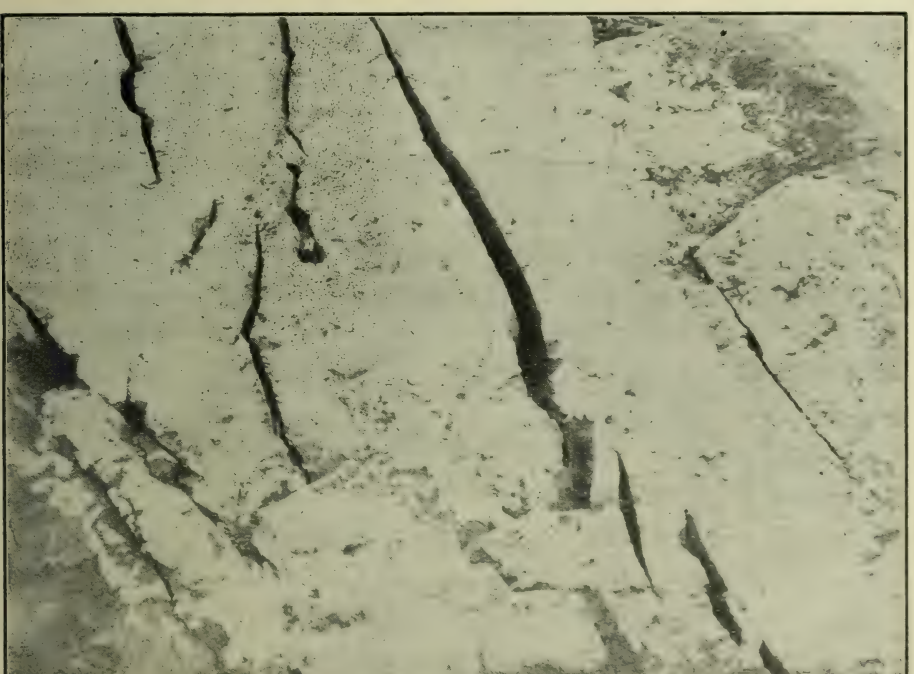


Fig. 19. Part of rock surface in Fig. 18 enlarged.

it is somewhat difficult at times to distinguish some phases of the Lower Huronian from the Keewatin. Those who have mapped the series in this way considered that the boulders and other fragments in the Lower Huronian represented pyroclastic rocks practically contemporaneous with the greenstones of the Keewatin, which were also deemed to be of sedimentary character.

Surrounding Sharp's Landing there are some interesting exposures. The Keewatin is here represented by an outcrop of iron formation which is only about 25 feet in length. Surrounding this or overlying it are slates and conglomerates of the Lower Huronian, which here dip at a higher angle than they usually do in the vicinity of Cobalt station. Near this Landing and along the shore, the Huronian is probably folded into anticlines and synclines, as there seems to be a repetition of certain beds. The most interesting point in connection with these outcrops is, however, the fact that we found fragments of the Keewatin iron formation in the overlying series.

The Keewatin rocks which outcrop around the shores and islands of Sasaginaga and Clear lakes are seen to be of at least two ages. The older rocks are light colored and fine grained and are often much fissured. They contain numerous stringers of quartz, especially near the north end of lake Sasaginaga. It is difficult to say what much of this light colored rock has been originally, although, from thin sections examined microscopically, it appears to have been a fine grained volcanic type. It is cut through by a later series which is somewhat like other exposures of the Keewatin seen in the district. A similar assemblage of rocks to those found at this lake occurs in the township of Boston to the northward. Usually the Keewatin is represented by darker colored rocks than those of most of the exposures around Sasaginaga.

The folding, shown by small cracks or torsion figures, which are present in many of the Keewatin outcrops, assists in their recognition. Many of these cracks are now filled with white calcite, and although on the whole the rocks look like slates of the Lower Huronian, these calcite fissures distinguish them. There are some good expo-

Fig. 20. Lower Huronian breccia—conglomerate formed *in situ* from Keewatin porphyry. The finger is on the latter rock. Lot 15 in the second concession of Bucke.

sures of this kind in the railroad cuts between Pickerel lake and Bass lake, two or three miles south of Cobalt station. Other smaller exposures of the rock in the railroad cuttings may be seen about opposite Short lake, just south of Cobalt lake, and certain outcrops occur not far east of the railway and south of Cobalt lake. The outlines of this area have been only approximately determined. Then we have shown an area just west of Peterson lake. It was found almost impossible to determine its boundaries accurately, and in this connection it may be said that if the slaty phases of the Lower Huronian have been metamorphosed, as they sometimes are in the vicinity of diabase intrusions, it become doubly difficult to distinguish them from the Keewatin. We have also shown Keewatin areas along the Montreal river between Hound Chute and Sandy portage. This area is probably much larger than shown on the map, as no attempt was made to trace it out in detail. Similar rocks are found around lake New.

Contact of Keewatin and Laurentian

Although the Laurentian granite covers an area of considerable extent on the map, we found only one good contact where the granite plays the part of an intrusive rock. This was near the northwest corner of what we have called Kirk lake. The granite here comes in contact with greenstone and sends out small dikes and stringers into it. This greenstone appears to be a variety of the Keewatin of the district. It is certainly older than the granite. A microscopic examination of the greenstone was not very satisfactory owing to the metamorphism to which it has been subjected.

The granite of the district is commonly rather coarse in grain and of a deep flesh-red color, the feldspar predominating. The ferro-magnesian constituent is biotite, which is usually converted to chlorite and occurs in small quantity. The predominant feldspar in generally microcline, and other acid varieties of plagioclase are abundant. The larger quartz grains frequently show a rounded outline.

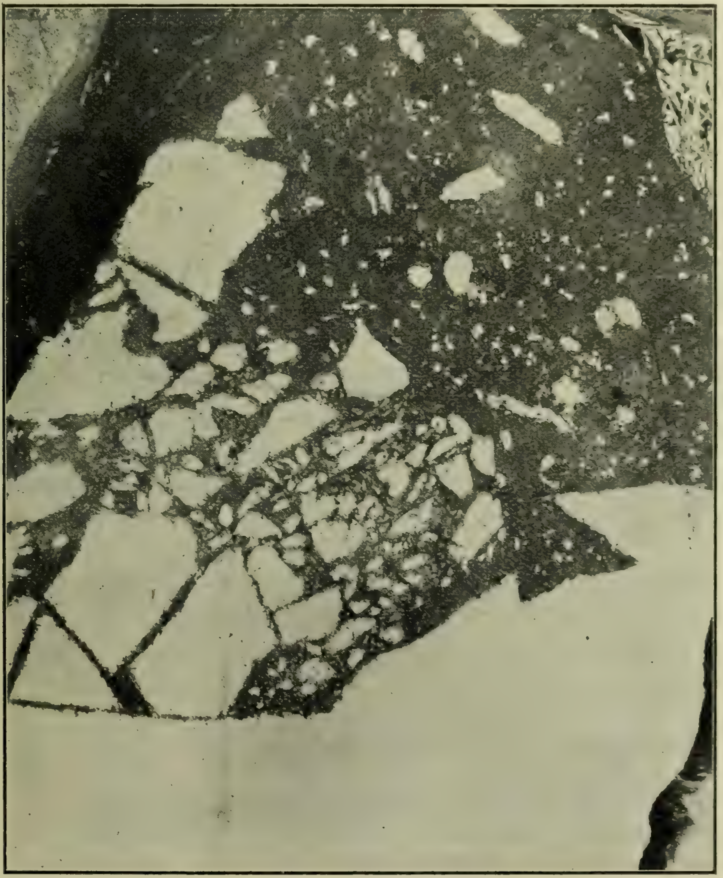


Fig. 21. Contact on shore of Temiskaming between the Keewatin and Lower Huronian. The Huronian breccia rests on the Keewatin rock from which it was derived. Lot 15 in the second concession of Bucke.

It would have been a source of satisfaction if we had been able to find more contacts of the granite with the Keewatin greenstones, but the writer thinks that the relationship which is shown by the legend on the map to exist between the rocks of this region is correct for the following reasons: (1) The Keewatin throughout the field has been much disturbed and now contains torsion cracks and other evidence of disturbance,

while the Laurentian granite does not show any traces of such disturbance. (2) The granite, as has just been said, cuts through the greenstone at the northwest corner of Kirk lake. (3) Boulders and other fragments of granite, similar to that which makes up the mass of the rock in Lorrain, are found in the Lower Huronian in many places, thus giving evidence, even if we had no contact between the granite and the Keewatin, that the Lower Huronian is younger than the granite. The writer has never seen any contact between the granite and the Lower Huronian. (4) The Middle Huronian is seen in contact with the Laurentian granite in numerous places in the township of Lorrain. In fact it is difficult to draw a line between the two series, the recomposed Middle Huronian material often resembling very closely the Laurentian granite from which it has been derived. A similar relationship between these series was described by Dr. Barlow in his Report of the region some years ago, the outcrops studied by him being on the Quebec side of Temiskaming in the vicinity of Ville Marie. At that time it was thought, however, that the granite was the oldest rock in the district, that is, older than the Keewatin, Lower Huronian and Upper Huronian, the three being put into one series.

In two or three instances pebbles in the Lower Huronian appeared to be conglomerate, that is, they seemed to indicate that there had been a conglomerate series before the Lower Huronian was laid down. The writer was not able to break out any of these pebbles so as to determine their character accurately. It is well, however, to consider the possibility of a fragmental series in the district older than what is here called the Lower Huronian. The Keewatin undoubtedly contains some sedimentary material, shown by the jasper-magnetite bands.

The breccia and conglomerate of the Lower Huronian are what were called by Logan and others slate-conglomerate, a name which well describes the varieties possessing a slate-like base through which are set pebbles and boulders. At times the fragments are angular in form. These rocks show great variety in composition, the conglomerate frequently containing pebbles of many kinds and of various sizes, the material being representative both of the Keewatin complex and of the Laurentian. Pebbles represent several diabases and porphyries of the Keewatin together with those of granite and other pre-Huronian rocks. In other cases the Lower Huronian fragmental rocks contain material of only one or two kinds, representative of an underlying or adjacent mass. Thus the slaty-greywacké members frequently represent the recomposed material of the Keewatin which was consolidated almost *in situ*. It is often difficult to distinguish the recomposed rock from that through whose decomposition it was formed.

Huronian

The map shows what we have called the Middle Huronian to be confined to the southeastern corner of that part of the area which belongs to Ontario. This series is here light in color, being composed essentially of granite debris. It is possible or even probable that there may be rocks of the same age on the western side of the area which differ in appearance from these Lorrain arkoses and other varieties. No outcrops of granite were seen in the western or northern part of the area; hence if rocks were being laid down in those parts of the field at the same time as they were being deposited in the southeast corner, the fragmental material, no granite being present, would be different in appearance from the Middle Huronian of Lorrain.

It may be seen from the map that the writer has roughly subdivided what he has called the Lower Huronian, the coarser fragmental material or conglomerate being shown to be essentially confined east of a line which runs from the east side of Mud lake northeastward towards New Liskeard. Some outcrops of this conglomerate or breccia were, however, found in the township of Hudson.

These rocks in the western part of the map resemble in a general way the greywacké slate which is associated with the conglomerate in the vicinity of Cobalt station

and elsewhere, but the slates along the railroad, for instance near the town plot of Latchford, are usually reddish banded and present a somewhat different appearance from the typical slates of the Lower Huronian. Reddish banded slates are found along the shore of Temiskaming, on the Quebec side, to the east of the area we have mapped.

Contacts are very frequently difficult to find. The writer was fortunate in finding a striking one, a specimen from which is shown in figure 22, on lot 4 in the twelfth concession of Lorrain. This contact is shown on the map. A small knoll of slaty greywacké here has the arkose around its base, and fragments of the dark graywacké are cemented, as shown in the figure, with the light colored arkose. This is the only contact that the writer was able to find between the Lower and Middle Huronian.

There are some things that are rather difficult to understand in connection with the Huronian sediment. The cement material, for instance, and the angular character of the greywacké fragments at the contact just described do not indicate water erosion. The cement material is very fresh in appearance and only slightly decomposed, thus differing from material which has been produced in the presence of water. The greywacké fragments being angular also show no evidence of having been worked over by water. The writer is not able to offer a satisfactory explanation for the character of the sediment found in some of these strata. As previously stated, other writers

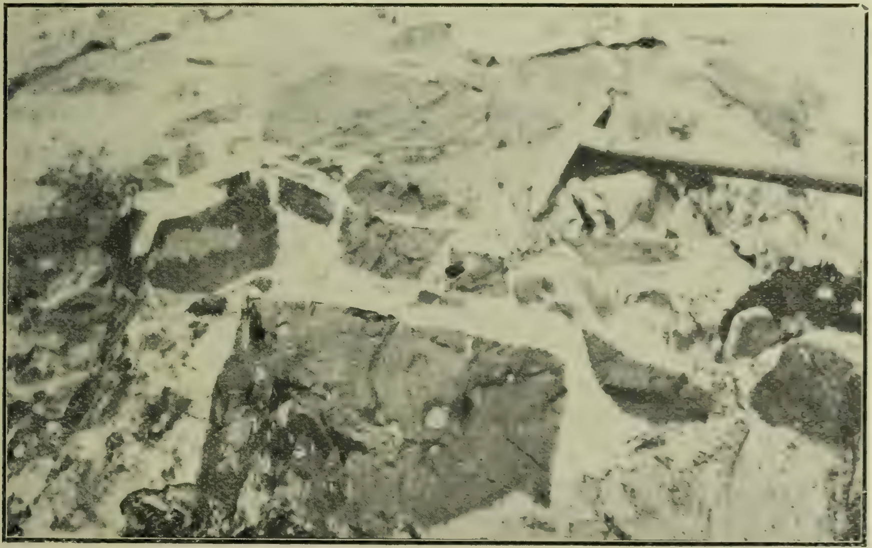


Fig. 22. Breccia at the contact of the Lower Huronian with the Middle Huronian. Fragments of greywacké-slate are cemented together by the light colored Middle Huronian arkose. Lot 4 in the twelfth concession of Lorrain.

in the district have claimed that all this fragmental material was pyroclastic in origin. The present writer has disproved this, the fragmental material at some of the contacts being clearly derived from the older series close at hand. To account for the undecomposed and angular character of much of the fragmental material, the writer is inclined to the belief that desert conditions prevailed in this region at the time some of the Middle Huronian rocks, at least, were formed. Of course, much of the material in the Lower Huronian, after we get above its base, and much of that in the uppermost part of the Middle Huronian is well rounded and shows the effects of water action.

The writer does not pretend to say that there is no pyroclastic material intermixed with the fragmental material of the Huronian. The association of some of the strata is puzzling. It is difficult to understand, for example, how certain large boulders of granite in the conglomerate, which forms part of the highest outcrops of the Lower

Huronian, have been carried so far from their parent masses. These large boulders are found over much of the district, and there are now no outcrops of granite in the neighborhood of many of them. Then some of the delicately banded greywacké slate may represent volcanic dust or fine grained pyroclastic material. In the present state of our knowledge we have little warrant for claiming that the granite boulders, often two or three feet or more in diameter and distant a couple of miles from exposures of the rock, indicate glacial conditions during Lower Huronian times, although we have no proof to the contrary.

Analysis of Slate

The sample analyzed is from the well-banded, what I have called greywacké-slate, from the base of the cliff at the Little Silver mine in the southwest corner of location R L 404 (Frontispiece). Mr. Burrows found it to have the following percentage composition:

	Per cent.
Silica	62.74
Alumina	16.94
Ferric oxide	5.07
Ferrous oxide	1.59
Lime	1.39
Magnesia	3.05
Soda and potash	6.07
Moisture	.36
Loss above 110 degrees	3.20
Total	100.41

Analysis of Breccia

A sample of the medium grained breccia, in the wall of the La Rose vein, was submitted to analysis by Mr. Burrows, with the following result:

	Per cent.
Silica	43.12
Alumina	19.74
Ferric oxide	5.72
Lime	5.40
Magnesia	7.48
Soda	4.50
Potash	1.75
Cobalt and nickel	.55
Loss on ignition	10.94
Arsenic	1.18
Total	100.38

The sample showed in places the greenish arsenate of nickel and also bright specks of a white mineral, evidently smaltite or chloanthite.

Diabase and Gabbro

These rocks, as will be seen from the map, occupy a considerable part of the area. Good contacts are found, especially between them and the Lower Huronian. A contact of diabase with the Middle Huronian can be seen along the shore of Temiskaming a short distance north of Martineau Bay and elsewhere. One is struck by the fact that in many of these contacts the fragmental rocks, through which the diabase and

gabbro cut, frequently dip towards the diabase. This is rather unusual. We generally find fragmental rocks dipping away from the intrusive varieties or forming anticlinal structures. The diabases and gabbros here, as shown on preceding pages, formed, in many cases, laccolitic masses and sheets or sills at one time (Fig. 17). Hence it is probably to be expected that the slate and conglomerate series should dip towards outliers of the diabase and gabbro which rest on them. A contact of the slate with diabase is seen across the railway from the La Rose mine, and good contacts are also to be seen near the railway track a couple miles south of Haileybury. The slate on lot 15 in the first concession of Bucke has been much disturbed by the intrusion of the diabase, and a peculiar columnar structure, perpendicular to the bedding, has been developed in it. This has already been described (Fig. 16).

It was thought that the metals in the cobalt-silver deposits might have been derived from the diabase. Samples from different outcrops were, however, tested by Mr. Burrows, who found no indication of the presence of any of these elements. Keewatin greenstone was examined with similar results.

Elsewhere in this report it has been stated that these post-Huronian diabases

Fig. 23. Contact of Middle Huronian quartzite with Niagara limestone on the east shore of Lake Temiskaming, north of Piché Point. The fragments of quartzite are cemented together by limestone.

and gabbros are often much like some of the coarser varieties of basic rocks which are found in the Keewatin. Representatives of the latter, especially on freshly broken surfaces, have a more weathered and altered appearance than do post-Huronian representatives.

The writer has not thought it necessary to make a detailed examination of the post-Huronian diabases and gabbros, owing to the fact that this would not have much economical bearing, and further, these rocks have been described in Dr. Barlow's

Report on the Temiskaming map sheet published in 1897. The reader desirous of details concerning these rocks should refer to that Report.

It may, however, be noted here that these diabases, while they may belong to about the same period of eruption as some of the basic eruptives in the vicinity of Sudbury, are different from them in character. We have no rock here which closely resembles the norite of Sudbury. About the middle of the southwest shore of Cross lake there are outcrops of a basalt which cuts the diabase, in which, a little further to the westward occur the Stringer, Handy and other cobalt-silver veins. In hand specimens this basalt is seen to be very fine grained, especially near the contact. Under the microscope the constituents of the rock, which is quite fresh, are seen to be in two generations. The most prominent mineral is plagioclase which occurs both as phenocrysts and in the ground mass in needle-like crystals. A light colored pyroxene occurs more sparingly than plagioclase. It is found both as phenocrysts and in grains in the ground mass. The pyroxene phenocrysts are older than those of plagioclase. A very few grains of olivine are present in some of the thin sections.

Fig. 24. La Rose mine, May, 1904.

Analyses of Cross Lake Rocks

	No. 1.	No. 2.	No. 3.
Silica	45.20	49.84	48.06
Alumina	19.08	18.94	18.23
Ferrous oxide	14.64	6.40	9.57
Ferric oxide	3.64	1.51	
Lime	7.89	10.32	11.55
Magnesia	4.98	7.39	7.80
Soda	3.32	1.99	1.87
Potash	1.08	1.28	.27
Loss on ignition	......	2.57	3.54
Totals	99.83	100.24	100.89

No. 1 is the basalt described above. No. 2 is the diabase or gabbro cut by the basalt. This gabbro, near the point mentioned on Cross lake, is seen to overlie a fine-grained representative of the fragmental series.

No. 3 is an analysis made in the Pittsburg Testing Laboratory of a specimen of gabbro taken two feet away from the Handy vein and about six feet from the surface. The result of this analysis was given to the writer by Mr. J. O. Handy, who says that a thin section of the rock examined microscopically showed predominant hypersthene, much augite, plagioclase, magnetite and no quartz. This specimen is seen from the analysis to possess almost the same chemical composition as No. 2. The Handy claim lies a short distance west of the foot of Cross lake.

In the western part of the field the diabase and gabbro frequently contain grains of reddish feldspar. In the township of Hudson narrow veins with niccolite and smaltite have been found in this rock.

Lake Superior Silver Deposits

The Silver Islet mine and the silver mines on the main shore to the southwestward of Port Arthur are well known to students of ore deposits. In richness of silver they resemble those of Cobalt station, but they contained a much lower percentage of cobalt, nickel and arsenic. Cobalt bloom and nickel bloom, together with arsenides and other compounds, were, however, found in these lake Superior deposits with the silver. A similar assemblage of minerals, but in a much smaller quantity, was briefly described years ago as occurring on Michipicoten island. It is well known that native silver occurs in association with native copper in the great copper mines of Michigan on the south shore of Superior. It would seem then that native silver is not a very rare mineral in the region between the Quebec boundary and the north and south shores of lake Superior. Port Arthur, however, lies about 500 miles west of Cobalt station, and in the intervening area no deposits of the metal have been found. There is ground for hope that deposits will be discovered when this area is explored. Little is known about much of it at the present time.

The Port Arthur Mines

Much has been written on the silver mines in the area adjacent to Port Arthur. This literature has been summarized and many additional details given in an important report written by Mr. E. D. Ingall of the Canadian Geological Survey.[9] None of these mines are now working.

It will be seen from the following notes, condensed from Mr. Ingall's report, that these Port Arthur deposits in many respects, especially in the facts that they occupy for the most part vertical fissures which cut slightly inclined pre-Cambrian beds and in their mineral contents, resemble the silver-cobalt deposits in the vicinity of lake Temiskaming. The chief difference between the two as regards their mineral contents is that the Port Arthur deposits contain a higher percentage of gangue material, the ore usually occurring in bunches or pockets, and the percentage of silver is always much higher than that of the associated nickel and cobalt which generally occur in small quantities or are entirely absent in some of the deposits. Some of the veins in the vicinity of lake Temiskaming on the other hand contain a much smaller amount of gangue, and the percentage of cobalt, nickel and arsenic is often higher than that of silver. One of these veins, that in the northwest corner of R L 404, as shown above, consisted as exposed at the surface of about 14 inches of solid smaltite together with niccolite. There was little gangue in this ore. The Cobalt station deposits, as previously stated, resemble, among veins which have been worked in the world, more closely those of Joachimsthal in Austria and Annaberg in Saxony than any others.

[9] "Report on Mines and Mining on Lake Superior," by E. D. Ingall, Part H Annual Report of the Geological Survey of Canada, 1887, 124 pages.

It is interesting to know, however, that nickel did occur in the Silver Islet mine, at least, in economic quantities. The first ores of this metal of this Province, which is now such an important producer of the metal, were those of the Silver Islet mine. Mr. W. M. Courtis, in a paper read before the American Institute of Mining Engineers, October, 1873, in speaking of the smelting works at Wyandotte, says that the matte was treated to save the nickel and that the silver was extracted from the marketable nickel speiss.

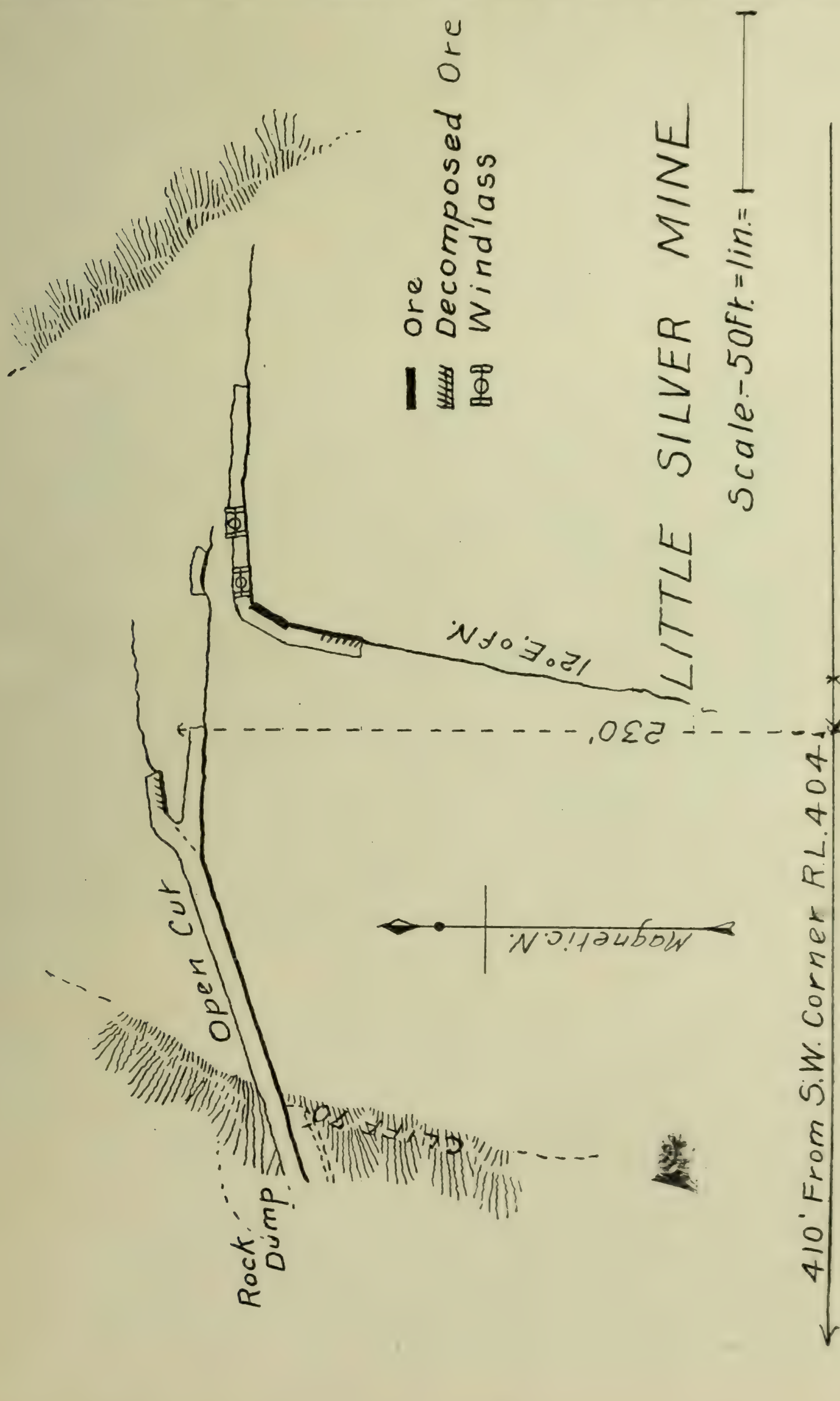
Ingall says the vein-filling minerals consist of quartz, barite, calcite and fluorite. In these occur different metallic minerals, viz.: blende, galena, pyrites of various species and occasionally some sulphurets of copper, whilst the silver occurs as argentite and in the native state, the former being the more common. At places the veins carry a dark green, probably chloritic, material, which on some surfaces has a bright waxy lustre, whilst occasionally a soft, greasy talcose material, probably saponite, accompanies the ore, notably at the Beaver mine, and to a lesser extent at one or two other places. Carbon in various forms has also been found here and there, whilst in some of the vugs in the veins which have been found near the surface stiff clay and ochreous

Fig. 25. La Rose mine, Cobalt, June, 1905.

material have sometimes been obtained along with nuggets of argentite, the former, however, having evidently been washed in from the surface and thus imbedded the silver minerals already existing in the vugs.

The same writer further states: "These then are the mineral constituents of these veins, but the Silver Islet vein forms somewhat of an exception in that it carried, besides these, various arsenical and antimonial ores of silver with compounds of nickel and cobalt and other metallic minerals which have so far not been found in the rest of the veins.(?) Other salient features were the pink and cream-colored dolomitic spar which so frequently formed a characteristic and prominent constituent of the

gangue of the rich ore, and the predominance of native silver in the rich parts, whereas in the rest of the veins, though this form of silver occurs in considerable quantity at places, yet argentite seems to be the form in which it is generally found."



"Again, it is interesting to know that both the mineral waters and the inflammable gas that were met with in opening up the Silver Islet mine have also been encountered at other points in the district. At the Rabbit Mountain mine in one of the lower levels I saw water running over the breast of the drift which gave off a faint odor of sulphuretted hydrogen and was depositing a white flocculent material, whilst both at this place and at the Beaver mine I was informed that small quantities of inflammable gas had been met with."

These veins, like those of Temiskaming, frequently present a brecciated appearance, angular fragments of rock being enclosed in the vein material.

Ingall found the distribution of the silver minerals in the veins very irregular, the rich ore generally occurring in detached bodies of varying dimensions surrounding very poor or quite barren areas of the vein.

As regards the metallic minerals, it was observed by Ingall that the blende comes first in importance, being the most plentiful. This mineral is practically absent in the Temiskaming deposits. The galena does not play such an important part, Ingall says, as the blende. Pyrite is found to a lesser extent than the two last mentioned minerals. Both pyrite and galena are likewise rarely met with in the Temiskaming veins. Marcasite and pyrrhotite are found in the Port Arthur veins, but copper compounds represented by chalcopyrite and copper-glance are rare. Through these minerals, or through the gangue minerals, are distributed the argentite and native silver. It is said that, with the exception of Silver Islet, the native silver is more characteristic of the ore bodies near the surface and is replaced by argentite in depth. The likelihood of blende, galena and pyrite carrying silver is asserted to be in the order in which they are here named. Silver was found in but few specimens. Some traces of gold were obtained in these minerals in a few instances.

The calcite is said to be apparently older than the quartz, and there is also some secondary calcite. The silver minerals seem to be due to a later infiltration of silver-bearing waters subsequent to the deposition of the gangue minerals.

Regarding the source of the silver minerals Ingall does not offer any definite theory. He says some writers have thought them to be connected with the trap eruption, the silver being brought up by thermal waters accompanying these intrusions. He points out, however, that these fissures intersect and dislocate the trap sheets and dikes. He adds that the fact remains that all the ore bodies occur near or within a reasonable distance of trap in some form, either in dikes or in sheets. This suggested the idea to him that the silver may be derived by decomposition of some of the mineral constituents of the trap carrying minute quantities of silver. On decomposition, waters infiltrating downwards through the fissures might have deposited their silver contents in them. He thinks that the various forms of carbon present in the sedimentary rocks may have had some influence in effecting this precipitation.

Silver Islet Mine

This deposit, which occurs on an islet, less than 80 feet in diameter, about a mile out in the lake off Thunder Cape, was discovered in the summer of 1868. It is the most famous silver mine yet worked in Canada, the silver produced from it amounting in value to \$3,250,000. The vein on this islet intersects what is called a chloritic diorite dike in its course through the sedimentary beds of the Animikie. The producing part of the vein was practically confined to that portion between the walls formed of the dike material.

We shall not attempt to give a fuller account of this vein here, but shall refer the reader who wishes more details to Mr. Ingall's interesting report. It will be well, however, for the purpose of comparison to give a list of the minerals found in this vein. Among these are the gangue minerals calcite, quartz and dolomite, the latter varying in color from cream to pink according to the amount of manganese contained. A variety known as rhodochrosite is said to have been found. The metallic minerals

are native silver, argentite, galena, blende, copper and iron pyrites with marcasite, tetrahedrite, domeykite, niccolite and cobalt bloom, together with a mineral known as macfarlanite containing arsenic, cobalt, nickel and silver. Two new minerals are said to have been found in the ore; these were called huntilite and animikite, those with macfarlanite, according to one writer, being the principal producing silver ores of the mine. There were also found, annabergite, antimonial silver and cerargyrite, the latter "where the rock has been decomposed." Graphite is said to occur in quantity. A curious feature of the vein was the combustible gas met with in large quantities in the workings and the mineral water which carried considerable amounts of chloride of sodium and other metals. Two very rich bunches or bonanzas of ore were found in the vein. One of these was completely worked out by 1874, yielding over $2,000,000. The shape of this bonanza was that of an irregular pear, and throughout its extent in both veins, that is the main and branch vein, it was accompanied by a strong impregnation of graphite. The bulk of this bonanza was arborescent silver more or less mixed with macfarlanite, a rich ore of silver carrying 78 per cent. of that metal along with arsenic, cobalt and nickel. Its physical structure resembles niccolite.

Fig. 27. Underground View at La Rose Mine, 1905. (From a photograph by Mr. A. de Romeu.)

In drifting south on the third level in 1878, strong impregnations of graphite were met on the hanging wall which were soon followed by the second bonanza. This deposit of silver was remarkable for its great width, five feet solid across the breast, and the occurrence in great quantity of the two previously unknown compounds of silver, animikite and huntilite. The shape of this bonanza was that of an inverted cone with a base of about 50 feet on the third level, with the apex down as far as the fifth level. This deposit was phenomenal in its structure, and a winze in the middle of the deposit to the fourth level, 60 feet, was sunk literally through native silver, the metal standing out boldly from the four walls of the winze. In the breast of the drift it stood out in great arborescent masses in the shape of hooks and spikes, in gnarled, drawn out and twisted bunches, followed by arborescent silver with intercalated bands of animikite and huntilite. The width of the vein was over 10 feet, and the entire deposit, including the stamp rock, yielded about 800,000 oz. of silver.

While the vein continued to the greatest depth reached in the shaft, over 1,200

feet, little ore was met with in the lower workings, no silver being obtained from great stretches of vein material.

To give an idea of the richness of the ore produced from this vein in the earlier part of its history, it may be said that the 1,154,537 lbs. of ore produced up to the season of 1872 averaged $1,322.44 per ton. Silver then sold, however, at more than twice its present price.

Ores of other Lake Superior Mines

In order to show the character of the minerals found in other deposits of the Port Arthur area we may cite the following examples given in Ingall's report. Argentiferous blende was the chief silver-bearing ore of the vein on McKellar's island. On Spar island the metallic minerals were copper-glance, copper pyrites, zinc blende and a little argentite. Prince's mine, the oldest mine on the Canadian shore of the lake, having been worked in 1846 or 1847, appears to have been regarded more in the light of a copper than of a silver-bearing vein. It contained native

Fig. 28. Cobbing and sacking ore at the La Rose mine, November, 1904.

silver disseminated in thin laminae through the calcareous spar and blende. Argentite was also found in this vein, and the calcareous spar was stained with blue and green carbonates of copper and with arseniate of cobalt. The vein on Pie island contained blende, galena and iron pyrites.

The veins so far mentioned belong to what Ingall calls the Coast group. In the second or Port Arthur group he says the silver veins may be considered in two divisions: (1) Those which occur in the Animikie rocks; (2) Those occurrng in the Archean area to the north of the former. Most of the veins are contained in the first division. A number of veins are described by Mr. Ingall under this heading. The Shuniah or Duncan mine is interesting owing to the fact that the vein here passes downward from the Animikie rocks into the underlying Archean, which consists of what are called diorite, syenite, felsite, etc. It is said that no silver was found in that part of the vein

contained within Archean walls. At the 3A mine the gangue was mostly quartz with a little calcite through which were distributed ores of iron, copper, lead, zinc, nickel and silver, with some cobalt and gold as shown by the assays. The silver was found native and combined with sulphur and nickel. One sample of the ore is said to have assayed 1.4 per cent. of cobalt and 25 per cent. of nickel. This vein was in what Ingall calls the Archean or Huronian, the rocks being gray dolomitic schists associated with dark-green compact diorite, whilst dark grayish red, felsitic syenite occurs a short distance to the south. Near the 3A mine was a vein containing 2 feet of milky quartz, which is interesting on account of the fact that it was said to carry native bismuth, the only mention made of this mineral, which occurs in most of the Temiskaming deposits. The Emmons' mine, on lot A in the township of McIntyre, is said to have contained mispickel, another mineral whch seems to be rare in the vicinity of Port Arthur.

Fig. 29. Prospectors at Cobalt, May, 1904.

Rabbit Mountain Group

This group of mines, which was discovered a number of years after the Silver Islet and other veins of the Coast group, is said to present somewhat different conditions of occurrence from those just mentioned. The veins are all in the Upper argillaceous division of the Animikie with its associated trap sheets. The ore of the Rabbit Mountain mine consists of native silver and argentite with other minerals. A special feature of the Porcupine mine, one of this group, is that it carries witherite, the carbonate of barium. In the Beaver mine there is the occurrence of saponite already mentioned.

The Silver Mountain group presents features similar to those of the group just referred to. The veinstones are calcite, barite and quartz with fluorite. The enclosing rock is argillite. The metallic minerals are represented by blende, both light and dark-colored, galena and iron pyrites, with occasionally a little copper pyrites, the silver occurring both native and as argentite.

Woodside's vein differs from the others in the area in that it occurs in the Archean granitic and gneissic rocks underlying the Animikie. The vein in its nature and contents is very similar to the rest, and carries blende, galena and pyrites distributed through the usual gangue in moderate profusion.

There is also what is called the Whitefish Lake group. The veins here mostly occur in the lower silicious rocks of the Animikie. They have much the same contents as the preceding ones.

Minerals of Port Arthur Veins

With the object of comparing the minerals of the Port Arthur silver mines with those of the Temiskaming veins, the following table has been prepared from the minerals mentioned by Ingall as occurring in the former:

I. Native elements:
    Native silver, native bismuth, graphite.
II. Arsenides:
    Niccolite, domeykite, macfarlanite (?), huntilite (?).
III. Arsenates:
    Cobalt bloom, annabergite.
IV. Sulphides:
    Argentite, zinc blende, galena, pyrite, marcasite, pyrrhotite, chalcopyrite, copper glance.
V. Sulph-arsenide:
    Mispickel.
VI. Antimonide:
    Animikite.
VII. Sulph-antimonide:
    Tetrahedrite.
VIII. Chloride:
    Cerargyrite.
IX. Carbonates:
    Malachite, azurite, witherite.

The vein filling materials are quartz, barite, calcite, dolomite, rhodochrosite and fluorite. Chlorite, saponite, inflammable gas and mineral water were also found.

Many writers appear to have held that the trap or diabase and gabbro which overlies the Animikie rocks in this region represented a vast surface flow. In a paper published some years ago Dr. A. C. Lawson showed, however, that this trap, together with the layers of the same material which lie at a greater depth in the Animikie, is intrusive in character (Fig. 17). His work proved that these traps are of the nature of intrusive sheets or sills and that they are not only younger in age than the Animikie but that they belong to post-Keweenaw times.[10]

OTHER CANADIAN NICKEL-COBALT ORES

The following extract from the Report of the Geological Survey of Canada for 1890-91 summarizes a number of the known occurrences of nickel and cobalt in Canada at that time.

"It may not be amiss to draw attention here to certain other nickel and cobalt ores, or minerals containing a noteworthy amount of one or the other of these metals, which have from time to time been met with in Canada in the course of this Survey's work.[11]

"One of these, described as a steel-gray pyritous ore, from the Wallace mine on Lake Huron, was found by Dr. T. S. Hunt to contain 13.93 per cent. of nickel. Of two others found on Michipicoten island, Lake Superior, the one was shown by Dr.

[10] Bulletin No. 8, Geological Survey of Minnesota, 1893.
[11] P. 47 R.

Hunt to be an intimate mixture of the arseniurets of copper and nickel; different portions of the same mass affording him from 17.03 to 36.39 per cent. of nickel, whilst the other, also examined by Dr. Hunt, proved to be a hydrated silicate of nickel which, after drying at 100°C., was found by him to contain 30.40 per cent. oxide of nickel, (equivalent to 23.91 per cent. nickel). The arsenide of nickel, which for present purposes may be regarded as consisting of 44.1 of nickel and 55.9 of arsenic, has also been found at the 3A mine, on lot 3A of the township of McGregor, district of Thunder Bay, where it occurs in somewhat large nodular grains and nuggetty bunches, together with native silver, of a similar form, freely disseminated through a gangue of calcspar with some quartz. The foregoing are all rich ores of nickel, and should the deposits on further exploration be found to yield a sufficiency of the material these would, as available sources of this metal, prove of economic importance.

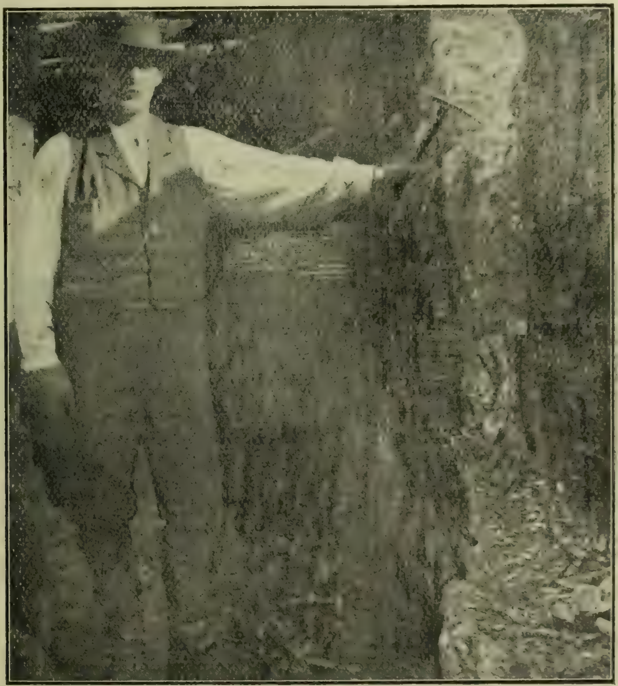


Fig. 30. A Cobalt pioneer and his vein.

"Less important, by reason of their occurring only in limited quantity or as containing but a relatively small amount of nickel or cobalt, are the following:—Millerite or nickel sulphide, a rich and valuable ore of nickel, occurs in small grains and prismatic crystals disseminated through a mixture of chrome-garnet and calcspar in a vein on the east side of Brompton lake, in the township of Orford, Province of Quebec. It is also reported to have been observed, in the form of prismatic crystals, disseminated through certain portions of the nickeliferous ore of the Copper Cliff mine, in the township of McKim, district of Nipissing, Ontario. Erythrite or hydrous cobalt arsenate, a valuable ore of cobalt when met with in quantity, is mentioned by Dr. Hunt as occurring in rose-red incrustations on calcareous spar at Prince's mine on lake Superior. Smaltite, a cobalt arsenide, was observed by Mr E. B. Kenrick in the form of minute crystals in a sample of copper pyrites (brought to the Survey for examination) from the township of McKim, district of Nipissing, Ontario. A sample of iron-pyrites from the seigniory of Daillebout, Joliette county, Province of Quebec, was found by Dr. Hunt to contain 0.55 per cent. of oxide of nickel (equivalent to 0.43 nickel) mixed with

cobalt, and a brilliant compact variety of iron-pyrites from Elizabethtown, Leeds county, Ontario, yielded him from 0.5 to 0.6 per cent. oxide of cobalt (equivalent to 0.39 to 0.47 cobalt), whilst a sample of iron-pyrites from Londonderry, Nova Scotia, was found by me (Rep. Geol. Surv., Can., 1874-75, p. 316) to contain 0.81 per cent. of cobalt and 0.14 per cent. of nickel."

The mineral danaite was found some years ago in developing nickeliferous pyrrhotite on the north half of lot 6, concession 3 of the township of Graham. Specimens of the mineral were found to carry about 4 per cent. of cobalt.

Cobalt bloom has also been found on magnetite at the Dominion mine and at the Cross mine, lot 2 in the second concession, in the township of Madoc, Hastings county.

In the western part of the Province the mineral occurs in small quantity at the southeast corner of the Bay of Islands, Bad Vermilion lake.

In the Report of the Geological Survey for 1848-9, page 61, T. Sterry Hunt has this to say concerning the ore of the Wallace mine at the mouth of the White Fish river, a partial examination only having been made of it:—

"The specimen was a mixture of a steel gray arseniuret, the species of which I have

Fig. 31. La Rose vein.

not yet determined, with white iron pyrites and probably some arsenical sulphuret of iron."

The percentage of cobalt in this ore was slight, only a fraction of one per cent., while the nickel ran about eight per cent. He further says:

"The Wallace mine is the second place in which cobalt has been detected in Canada. I have already noticed it in the form of arseniate of cobalt, forming reddish crusts upon calcareous spar, at Prince's location on lake Superior. In this locality it is associated with vitreous copper, green and blue malachite and native silver, while other parts of the same vein yield native silver, vitreous silver, blende and copper pyrites; in this connection it may be mentioned that a mass of the silver ore selected by myself from some hundreds of pounds, as an average sample, gave on assay 3.6014 per cent. of

silver, equal to 72 lbs. to the ton of ore. A portion of the silver extracted by a furnace assay from this ore was found on examination to contain a small portion of gold amounting to about one part in 7,000 of silver."

Speaking at this early date Hunt made the remark which after the lapse of a lifetime reads like a prophecy: "The detection of a small portion of cobalt in association with these metals upon the shores of lake Huron should lead us to look for deposits of this rare and valuable material."

FOREIGN COBALT DEPOSITS

Germany and Austria

Known deposits of cobalt-silver ore in other countries which resemble, most closely, those in the vicinity of Cobalt station, are found in Germany and Austria. The two principal areas in these countries are those of Joachimsthal and Annaberg. Mining was begun in the former at the end of the fifteenth or in the early part of the sixteenth century. The deposits of the latter, it is said, were discovered in 1492, a year which possesses special interest for inhabitants of this continent, for then Christopher Columbus first sighted its shores.

The ores of these two regions are similar to those of Ontario, and include compounds of cobalt, nickel, bismuth and silver, with the ore of uranium, which has not been found in the Ontario deposits. With these are silver ores of various kinds. The rocks belong to the older systems, but are different in composition from those of Cobalt.

An outline of the history of the cobalt industry at Schneeberg, another German area which contains ores similar to those of Cobalt, Ontario, is given in the appendix to this report.

At Joachimsthal, in Bohemia, there is a series of mich schist, calc schist and limestone which is cut through by dikes of basalt. The veins are said to be older in age than the diabase and cut all of the other rocks mentioned. The veins are narrow and contain quartz, hornstone, calcite and dolomite as gangue material, and they often show a brecciated structure[12]. The minerals in these ores are embraced in the following list:—

(1) Silver ores (native silver, argentite, polybasite, stephanite, tetrahedrite, proustite, pyrargyrite, sternbergite, argentopyrite, besides rittingerite, acanthite and cerargyrite).

(2) Nickel ores (niccolite, chloanthite, millerite).

(3) Cobalt ores (smaltite as well as bismuth-bearing linnæite and asbolite).

(4) Bismuth ores (native bismuth together with bismuthinite and bismuth ochre).

(5) Arsenic ores (native arsenic, arsenical pyrites).

(6) Uranium ore (uraninite or pitchblende).

With these are galena, zincblende, pyrite, marcasite, copper pyrites and others.

Among these ores those of cobalt and nickel are generally the older; those of silver the younger. The veins cut through dikes of quartz-porphyry, and are in turn cut across by basalt and later dikes.

Of similar composition to those of Joachimsthal are the veins of Annaberg in Saxony. In this neighborhood the rock is gray gneiss. There are two groups of veins in the district, the younger carrying the silver-cobalt ores. These are the most important of the ore bodies. The gangue material is chiefly heavy-spar, fluor-spar, quartz and brown-spar with various cobalt, nickel and bismuth ores, namely: chloanthite, smaltite, red and white nickel pyrites, annabergite, native bismuth, rarely bismuthinite. Of the silver ores there are pyrargyrite, proustite, argentite, native silver, silver chloride, and finally iron pyrites. The subordinate minerals are the gangue materials, hornstone, chalcedony, amethyst, calcite, aragonite, kaolin, gypsum; among ores are copper pyrites, galena, zincblende, marcasite, tetrahedrite, siderite, uraninite, uranochalcite, uranochre, gummite, native arsenic.

[12] Beck: "The Nature of Ore Deposits."

The great amount of chloride of silver, which was mined on a large scale at one time, is interesting. The structure of the veins is irregular.

From more than 200 observations which have been made the following is given as the relative ages of the various minerals of the Annaberg veins:—

V. Decomposition products, for example, annabergite and cobalt bloom.
IV. Silver ores and native arsenic.
III. Calcite and uraninite.
II. Brown-spar and cobalt-nickel-bismuth ores.
I. Heavy-spar, fluor-spar and quartz.

The silver-cobalt veins cut across the older tin and lead veins of the district as well as the dikes of microgranite and lamprophyre. The latter, especially, is often cut by the silver-cobalt veins. These are cut by basalt, which occurs not only in true dikes, but also in boss-like forms.

Somewhat similar silver-cobalt ores are found in certain veins at Schneeberg, but they are not so strikingly like those of Temiskaming, in mineral composition, as are those of Joachimsthal and Annaberg.

A like association of ores is found at Wittichen, where the veins occur in granite.

In 1904 only one cobalt-silver mine in Germany had a production worth consideration. This is in the Schneeberg field. Its output was valued at about $132,147. The values were in silver, cobalt, nickel, bismuth, arsenic, uranium, samples, etc. The works in which these ores are treated in Germany are at Schneeberg and are known as the "blue color works." Both the government and private companies are interested in the industry (See appendix).

According to Von Cotta, the Joachimsthal district consists of mica schist, together with more or less hornblende schist and crystalline limestone, the whole being cut by numerous dikes of quartz-porphyry and basalt. There are also two large granite masses which rise out of the mica schist. There are lodes of tin, silver and iron. Tin lodes are found only in the granite region. Silver lodes are divided into four groups tolerably distinct from one another. One set, which has a strike in a certain direction, contains about 17; another set has 21 lodes. There are also lodes which do not come to the surface. Both classes of lodes are said by Von Cotta to intersect the mica schist, with all its subordinate strata, quartz-porphyry and often even the dikes of basalt and wacké. This author also says that there seem to be cases where dikes of the last have intersected lodes or have penetrated into their fissures, from which it may be deduced that the silver lodes were almost contemporaneous with the formation of the basalt in that their fissures in part follow the basalt dikes, in part are intersected by the basalt. At all events they stand in a certain genetic connection to the porphyry, which here is evidently of much greater age than the basalt. The subject is still somewhat obscure. The silver lodes have not yet been found in the granite. Other writers do not agree with Von Cotta, as they appear to claim that the basalt is younger than the veins.

The following notes are taken from Phillips' "Ore Deposits," p. 436. The mountains known as the Erzgebirge lie on the boundary between Saxony and Bohemia. Joachimsthal lies on the Bohemian side, and is therefore an Austrian town, while Annaberg is in Saxony.

The country rock in the neighborhood of Joachimsthal is for the most part mica schist enclosed between masses of granite. In the eastern portions of the mine where there are some masses of included limestone, the lodes usually carry calcite as the predominating veinstone, but in the western part where the veins are not infrequently associated with dikes of porphyry, the gangue is almost entirely quartzose. There are seventeen veins striking north and south and seventeen others of which the direction is east and west. It has been constantly observed that the former exhibit a tendency to become enriched where they pass through the porphyry or included limestone, while the latter set of veins are not similarly affected when they come in contact with these

rocks. The ores raised contained values in silver, cobalt, nickel, bismuth and uranium. In the eastern division of the mine there are two shafts situated about 260 fathoms apart, the Einigkeit's shaft and the Kaiser Josef shaft (Fig. 32).

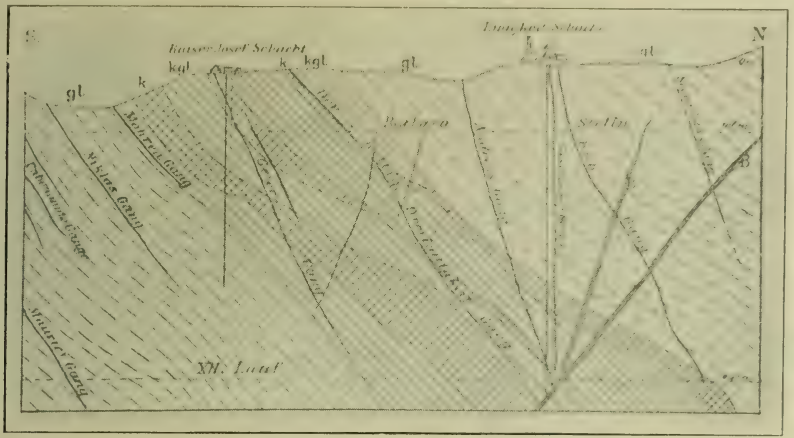


Fig. 32. Vertical section through the Kaiser Josef and Einigkeit shafts at Joachimsthal showing several narrow veins (gang), and dikes of diabase (B). The veins in mineral contents, size and distribution resemble those of Cobalt, Ont. (After Babanek-Beck).

In 1864 when the former shaft had reached a depth of 280 fathoms, a heavy outburst of water, at a temperature of 25 C. and evolving sulphuretted hydrogen, took place and greatly interfered with underground operations. It took two years before this water could be successfully tubbed off and mining proceeded with.

It is interesting to know that the uranium ores of Joachimsthal took on an additional value two or three years ago, when it was found that uraninite was the chief commercial source of radium.

The character of the ore produced will be seen from the following statement made by Phillips: —

During the period from 1877 to 1880 there were obtained 29½ tons of ore, containing 4,497 oz. of silver, 198 lbs. bismuth, 878 lbs. uranic oxide, 1½ tons arsenic and 314 lbs. of cobalt-nickel with a little lead, representing a total value of £1,687.

"About this time it became evident that the uranic oxide was the most valuable product of these mines, and workings were especially directed to develop the minerals yielding it. From 1881 to 1886 the average annual production was 38 tons of silver and uranium ores, worth about £6,520."

It is thus seen that these Joachimsthal veins, during late years at least, cannot be compared in richness with those of the Temiskaming district.

Chalanches, France

Somewhat similar silver, cobalt, and nickel ores occur in a network of narrow veins in crystalline schist at the Chalanches, in the Dauphiné, France. These deposits were discovered in 1767 and have had an interesting history. They were described some years ago by Mr. T. A. Rickard (Trans. Am. Inst. M. E. Vol. XXIV.)

The following extracts are from Mr. Rickard's interesting paper:

"In southeastern France, among the magnificent Alpine masses of the Dauphiné, there is a group of celebrated mines of silver, nickel and cobalt ores, the deposits of which present many features of interest. . . . . . .

"The discovery of these, as of many other notable mines, was accidental. In 1767, Marie Payen, a shepherdess (bergère) of Allemont, found an outcrop of silver ore, and brought away, in ignorant curiosity, a lump of heavy stone, which she handed to the

village smith. When tested on his forge, the molten silver trickled from it. The shepherdess received 600 francs upon her wedding day as a reward for the discovery. .

"The record of the Chalanches presents a story similar to that which is told of mines in more modern mining districts. The inaccessibility of the mines in winter,

Fig. 33. Cobalt Station, June, 1905.

the richness of the ore, its great fusibility, and the consequent systematic robbery of the silver are local commonplaces. Circumstances all worked together to make the Chalanches mines the prey of the most barefaced plunder. With the aid of a common forge-fire, even without the intervention of a crucible, and with little knowledge or skill, lumps of silver could be produced from the very rich chlorides, ruby silver and

Fig. 34. Physician's office, Cobalt, July, 1905.

black sulphides which constituted in the main the soft earthy ores or *terres* found in the crevices of the outcrop. Aged inhabitants still talk sportively of the theft like old smugglers and point out nooks in the woods which the remaining ruins of the little furnaces dug out by the miners, show to have been the scenes of former illicit silver-ore smelting. In these furnaces, no larger than an ordinary fire-place, dug in the

earth and smeared with clay, with charcoal, or, failing that, clods of dung for fuel, and two or three little urchins to blow, like cherubs on the old maps, out trickled the white metal. Clergy and people joined cheerfully in these moonlighting operations without in any degree shocking local ethics. The priest at Allemont, who lately restored the parish church, says that the old church had a room adjoining the sacristry in which a former reverend father used to melt down silver-ore brought to him by the faithful. The slags were concealed in an excavation under the floor, where a large accumulation of them was found when the church was restored. . . . .

"During the earliest period of mining at the Chalanches, some bodies of extremely rich ore were found near the surface. It is said that two shots produced sufficient silver to pay for the two buildings known as the pavilions of Allemont, with their various ornamentations, including the *fleurs-de-lis* which still adorn the roof. As 200 to 300 kilos. of silver would at that time be worth from $10,000 to $15,000, this statement does not seem incredible. . . . .

"It is not a little remarkable that although the silver is always associated in the lodes with rich nickel and cobalt ores, often with bunches of stibnite, and more rarely and erractically with gold, the government engineers took no notice of any metal other than silver. None of the valuable metals mentioned figure in the old accounts. The speiss containing nickel and cobalt was rejected with the slags, and went to fill the swamps and to form the road-beds, which, in later times were furrowed and turned over to recover their valuable contents. . . . .

"The possibility of utilizing three metals instead of one seems to have dawned upon the engineers quite as a discovery; and this fact stimulated the repeated spasmodic attempts to rehabilitate the old mine. The arsenides of nickel and cobalt were sold in England and Germany. More recently, a German chemist was employed at Allemont in an experiment to manufacture cobalt pigments for the arts. He was not successful, and the attempt was abandoned.

"In 1891 the gold value was first recognized. Its importance proved greater from a scientific than from a commercial point of view. The old mine-workings, aggregating 20 kilometers in length, showed that a great deal of unsuccessful exploration had been carried out. Search among the galleries, particularly near the surface, resulted in the finding of certain rich bunches of ore, which were soon exhausted. An attempt to introduce the tribute or lease system was made, with partial success. . . . .

The Ore Deposits

"The geological formation is simple. A net work of veins traverses crystalline schists of very variable character. The country forms a part of the great crystalline formation usually referred to as the Archaic schists of the Alps, though in point of fact they probably include rocks from the granite up to the Carboniferous. Lithologically, certain sections suggest the Huronian and Laurentian. These schists lie immediately upon the granite; they are extremely variable in character, so that at different places they can be described as gneissose, granitoid, talcose, micaceous, graphitic, or amphibolic. At the base of the slope leading to the mines there are superb blocks of rock containing crystalline epidote. . . . .

"The maps of the mine exhibit a wonderful network of galleries, spreading like a cobweb over an area of about 600 by 300 meters.

"It is computed that the workings aggregate in length not less than twelve miles, an extent in remarkable contrast to the relatively small quantity of ore produced. . .

"It has been thought by several observers that the lodes were more numerous near the surface than in the interior of the mine. This is due to the fact that any single fissure, in approaching the surface, spreads itself out into a number of subordinate fractures. It has also appeared that the lodes gained in regularity as they penetrated the mountain. Caillaux, therefore, adds that this fact seems to indicate the probable occurrence in depth of only a small number of lodes but that those surviving will have

a regularity greater than those which have been hitherto exploited. Regularity of structure would be a poor compensation to the miner for the fact that the enclosing rock is much harder, and the thickness of ore smaller, than in the ground nearer the daylight.

Fig. 35. Canadian Bank of Commerce, Cobalt, July, 1905.

Fig. 36. Canadian Bank of Commerce, Cobalt, November, 1905.

"The veins vary in width from a knife-blade to 80 centimeters (31.5 inches); their usual thickness lies between 3 and 30 centimenters (0.1 to 1 foot). . . . . . .

"Examination of the old workings proves clearly that with increasing distance from the surface the country gets harder, the veinstuff loses its soft character, the veins become fewer in number, more regular, less wide and less ore-bearing. Approaching the surface, on the contrary, the schists are fractured in a multiplicity of directions, the veins become larger, their filling is generally earthy and they throw off branches, at the intersections of which ore bodies are found. In general, mineralization becomes more pronounced with approach to daylight; this being due, not merely to the oxidation of the sulphides but to an actual relative increase of 'orey' matter. . . . . . .

"The observations made from day to day led me to conclude that the richest part of the mine was that which was within the influence of oxidation, and that both chemical agencies and structural conditions favored an enrichment of ore near the surface. This statement is particularly applicable to the silver contents. It also holds true of the gold, but it is less accurate with respect to the nickel and cobalt. The richness in silver of the oxidized ores suggests secondary precipitation. This is confirmed by the fact that the silver appears to be thrown down upon the nickel and cobalt arsenides, and often envelops them in such a way as to impart to them the rudiments of a nodular structure. The hard, undecomposed arsenides contain only small amounts of silver. The gold, only occasionally present, is associated invariably with soft, maroon-colored, earthy, iron-bearing vein stuff. The nickel and cobalt minerals appear to be primary ones, and are more persistent than those of silver and gold. . . . .

"If we accept the current theory that the nickel and cobalt came from the leaching of magnesian silicates, (and facts are numerous pointing that way), then, we must conclude that the origin of the nickel and cobalt of the Chalanches was not the immediately enclosing country, but rocks similar to it, which underlie it at a greater depth. The silver and gold, it may be suggested, were precipitated from other solutions, and at a period other than that which saw the deposition of the nickel and cobalt. The precious metals were probably derived from a deeper-seated source; and may have been leached from the granite which underlies the schists and is penetrated by the basic eruptives. In both cases the various metals must have come from a depth where leaching action was powerful, and from which ascending currents brought the metallic constituents, the subsequent precipitation of which produced valuable ore-deposits."

Norway

"The cobaltiferous fahlbands of the districts lying around Skutterud and Snarum occur in crystalline rocks varying in character between gneiss and mica schist, but from the presence of hornblende they sometimes pass into hornblende schists. These schists, of which the strike is north and south and which have an almost perpendicular dip, contain fahlbands very similar in character to those of Kongsberg. They differ from those of that locality, however, in as much as while here the fahlbands are often sufficiently impregnated with ore to pay for working, those of Kongsberg, although to some extent containing disseminated sulphides, are only of importance as zones of enrichment for ores occurring in veins. The ore zones usually follow the strike and dip of the surrounding rocks and vary in breadth from 2½ to 6 fathoms. The distribution of the ores is by no means equal, since richer and poorer layers have received special names and are easily recognized. The predominant rock of the fahlbands is a quartzose granular mica-schist or gneiss. The ores worked are cobalt-glance, arsenical and ordinary pyrites containing cobalt, skutterudite, magnetic iron pyrites, copper pyrites, molybdenite and galena. It is remarkable that in these mines nickel ores do not accompany the ores of cobalt in any appreciable quantity. The principal fahlband is known to extend for a distance of about six miles, and is bounded on the east by a mass of diorite which protrudes into the fahlband, while extending from the diorite are small dikes or branches traversing it in a zig-zag course. It is also intersected by dikes of coarse-grained granite which contain no ore, but which penetrate the diorite."[13]

[13]. Phillips, Ore Deposits.

These deposits, which at one time were among the world's chief producers of cobalt, are too low grade to be now worked at a profit.

New Caledonia

As the table given below shows, there have been during late years about half a dozen countries supplying the world with cobalt. The output of New Caledonia is much larger than that of any other country. It produces probably 85 or 90 per cent. of the world's supply.

Since the ore from Ontario has been put on the market the prices seem to have fallen materially in New Caledonia. It seems strange that Ontario should be practically the only competitor which this French penal colony, in the southern Pacific, has in both nickel and cobalt. The rivalry between the two countries in the production of the former metal has attracted attention for a number of years. It is now the more surprising that this Province becomes a competitor with the island in another way.

Fig. 37. Imperial Bank, Cobalt, November, 1905.

The cobalt deposits of New Caledonia occur under similar conditions to those of nickel and the two metals are frequently associated in economic quantities. The deposits of the two metals in Ontario, on the other hand, occur under conditions different from those of New Caledonia, and there appears to be little connection between the cobalt deposits of Temiskaming and the Sudbury nickel ores ninety miles to the south-west. The Sudbury ore consists of pyrrhotite and copper pyrites. It is associated with basic igneous rocks, the deposits being supposed to be of igneous origin. The cobalt-silver deposits, on the other hand, occur in distinct veins and are of aqueous origin.

New Caledonia is a non-glaciated country. Over a considerable part of its surface the immediately underlying solid rock belongs to the basic igneous group known as peridotite. This rock, like other basic varieties, weathers readily, and over a large part of the surface of New Caledonia it is represented by its alteration product, serpentine. The surface of this serpentine is more or less broken down, forming comparatively loose or slightly coherent deposits. It is in association with these that the cobalt is found, its ore being what is known as asbolite, earthy cobalt or cobaltiferous wad. Asbolite is

a mixture of oxides of cobalt, manganese and other metals. It can hardly be called a distinct mineral. It has been proved that the cobalt, nickel and other metals found in this decomposed rock were originally constituents of the peridotite.

The peridotites are believed by some writers to be post-Cretaceous in age, and are said to be in the form of a surface flow covering the uneven or eroded surface of the underlying Cretaceous strata.

They constitute the great serpentine formation of New Caledonia, and are high in magnesia and low in iron. They are more or less charged when fresh with crystals of pyroxene, uniquely ferro-magnisian, which lies between enstatite and bronzite. The unaltered rock belongs, therefore, in Rosenbusch's classification, to harzburgite. Dunite. which is composed of olivine with chrome iron ore and without pyroxene, is met with at times. These peridotites usually show traces of advanced alteration which results in the more or less complete transformation of olivine to serpentine, and in the development of talc from pyroxene. At times the alteration is complete enough to produce perfect serpentines, uniquely constituted of an aggregate of crystals of antigorite with some films of talc.

Since these rocks always contain a little manganese, nickel and cobalt, it would appear that these metals are integral of the olivine as well as of the enstatite. Grains of chrome iron ore are abundant in all samples.

The rocks are often traversed by dikes, less basic, of the character of gabbro, that is to say, rocks which contain feldspar and pyroxene. Diorites fine in grain or at times holding large crystals of hornblende sometimes outcrop in the middle of serpentine exposures.

Much of the mineral mined appears to contain only two or three per cent. of oxide of cobalt. After washing, it averages probably 4½ per cent. In one deposit described by Glasser, it is said that the decomposed material occupies a profound depression in the serpentine. This basin is filled by a red, clay-like deposit which has a depth of about 52 metres in the centre and 10 or 12 metres around the border. The richest ores appear to occur near the centre of the basin and near the contact of the serpentine.

It will be seen that all the cobalt deposits are irregular in form, and hence it is difficult to estimate their value.

The cobalt ore is all exported in the unrefined state.

The metal comes on the market in the form of oxide, CoO, which finds use in small quantities in several industries, the principal being that of pottery, where the blue coloration which it tends to give to the ware is employed to counteract the reddish tinge that traces of iron so often produce. It is also used to color porcelain. enamels and glass. The properties of metallic cobalt are remarkable. It would be used in alloys and for purposes to which nickel is put if it were as low in price as the latter metal. The different uses of cobalt, which absorb annually about 200 to 250 tons of oxide, guarantee a regular demand for the ore.[14]

Mr. A. Glasser, from whose "Report in 1904 to the Minister of the Colonies on the Mineral Wealth of New Caledonia" the foregoing is taken. states that New Caledonia has practically a monopoly of the production of cobalt in the whole world. He further says that while the deposits of the mineral are capricious they are at the same time numerous and extended.

This monopoly has now been broken by the discovery of the Ontario deposits.

At the time of Mr. Glasser's visit to the colony, the prices paid for cobalt ore were about as follows:—

Mineral with 4 per cent. CoO .... 330 Fr. a ton ($66)

Mineral with 3 to 3½ per cent. was paid on the same basis,
145 fr. and with an increase of .60 fr. for each 1-10 of
1 per cent., above ....195 Fr. a ton

[14] It may be added that the method of manufacturing blue cobalt glass has been known almost from pre historic times, as the glass has been found in the graves of the ancient Egyptians and in the ruins of Troy.

From 4 to 5 per cent., for each 1-10 of 1 per cent. above 4 per cent., there was paid .... .80 Fr.
From 5 to 6 per cent., for each 1-10 of 1 per cent. in excess of 5, was paid .... .90 Fr.
From 6 to 7 per cent., for each 1-10 of 1 per cent. above 6, was paid .... 1. Fr.
Above 7 per cent., for each 1-10 of 1 per cent., was paid.... 1.50 Fr.
On this basis mineral carrying 8 per cent. brings 750 Fr. ($150) a ton.

Production of Cobalt 1896 to 1900

Country.	1896.		1897.		1898.		1899.		1900.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
		francs		francs		francs		francs		francs
New Caledonia.................	4,823	482,300	4,757	475,700	2,373	237,300	3,294	336,000	2,438	275,500
New South Wales	....	....	....	....	119	14,000	193	22,975	145	39,750
Chili..........................	....	....	6	780	18	4,540	55	20,450	27	10,060
Spain..........................	18	9,000	13	17,000	....	....	....	....	....	....
Norway	19	13,500	24	13,500	21	10,800	....	....	....	....
Prussia	181	49,340	121	31,280	34	8,500	17	4,250	4	800
Total	5,051	554,140	4,921	538,266	2,565	275,140	3,559	383,675	2,614	326,110

1 franc=20 cents.

This total was augmented by some tons of complex mineral mined in different parts of Germany and Austria, from which a little cobalt was produced.

Taking the world's consumption of cobalt oxide, CoO, at 200 to 250 tons a year, as given above, the 2,614 tons of ore produced in 1900 would need to contain on the average over 8 per cent. of the oxide. The price of the ore averaged, as shown by the table, approximately 125 Fr. or $25 a ton. It may be added that cobalt oxide, CoO, contains 78.66 per cent. of cobalt and 21.34 per cent. of oxygen by weight. The Temiskaming ore is sold on the basis of metallic cobalt, not on that of the oxide as in New Caledonia.

New South Wales

The second largest producer of cobalt in the world has been New South Wales. The deposits in this country are situated near Port Macquarie and are similar in character to those of New Caledonia.

In 1903 the quantity of cobalt ore exported from the deposits near Port Macquarie amounted to 153 tons valued at £1,570.

South Australia

Cobalt ore, containing smaltite and other minerals, is found at Bimbowrie, near Olary, on the Broken Hill line, but little work has been done on the deposit.

South Africa

While silver has, as we have seen, been worked in association with cobalt, the latter metal has been very seldom found in association with gold in important quantities. Reference to only one such occurrence has been seen by the writer. This is in the Middleburg district in the northern Transvaal. Here in this non-glaciated district the gangue material, in the vein to which reference has been made, is kaolin, with which is mixed gold-bearing quartz. In the latter mineral are small nest-like aggregations of smaltite and copper ores, and at times molybdenite and the secondary minerals cobalt bloom, limonite and skoradite.

United States

Up to the present time there has been more or less production of cobalt oxide in the United States. Some of this came from the cobalt associated with the nickel ores at Sudbury, Ontario. In the process of smelting, which is now used at Sudbury, the cobalt is slagged out of the matte. Hence none of this metal will be produced in the future from Sudbury matte in the United States. According to the "Mineral Industry," in 1902 there was no production of cobalt oxide from domestic ores in the United States. In 1901, 13,360 lbs. of cobalt were derived from slag produced in the smelting of the lead ores at Mine La Motte, Missouri. In 1903 cobalt and nickel are said to have been discovered near Marion, Kentucky, in association with the fluorspar in that region. In the same year the Mine La Motte Company undertook the construction of a smelter and refinery for treating the nickel and cobalt ores obtained in connection with lead mining.

It is said that a few years ago one or two small trial shipments of cobalt ore from deposits in Grant county, Oregon, were made to France. The deposits in this county are described as occupying fissures in a dark greenish, more or less altered diabase-porphyry. They have a general northeasterly and southwesterly strike, and dip southeast. The ore bodies appear to be more or less lenticular in shape and vary from a few inches to several feet in width. The principal minerals are chalcopyrite, smaltite, arsenopyrite, pyrite, pyrrhotite, malachite and bornite with a quartz and calcite gangue. The values are chiefly in gold, cobalt and copper. Smaltite from a sample of the ore carrying this mineral and chalcopyrite was found by Mr. Burrows to have the following composition (No. 1). This smaltite had a rather unusual appearance, resembling somewhat acicular or fine columnar stibnite. In composition it is close to that from Gunnison county, Colorado, an analysis of which is given by Dana (No. 2).

	No. 1.	No. 2.
Cobalt	14.88	11.59
Nickel	1.12	trace
Arsenic	64.06	63.82
Sulphur	.57	1.55
Iron	11.14	15.99
Insoluble	2.22	etc.
Calcium carbonate	6.34	
Total	100.33	

Mexico

Cobalt-holding minerals have been found at several localities in Mexico. Little has, however, been published concerning these occurrences. Near the village of Pihuamo, state of Jalisco, cobalt minerals are found in veinlets cutting a large vein of magnetite associated with pyrite and pyrrhotite. The chief rock in the vicinity is described as andesite. It is said that some tons of ore have been mined which contained 8 or 9 per cent. of cobalt. The minerals are cobaltite together with small quantities of smaltite and cobalt bloom. The veinstones are calcite, slightly greenish, and a little barite. A little niccolite appears to be present.

The following Mexican localities are also said to contain cobalt minerals: Iturbide, in Chihuahua, Guanacevi in Duranago, Cosala in Linaloa, at the mine "Mirador" in Jalisco. It is said that the zinc in smithsonite is partly replaced by cobalt in Baleo, Lower California.

Chili

From the table on a preceding page it will be seen that Chili has been a producer of cobalt. References to the occurrence of the metal in that country are few, and the

writer is not able to say what the ores are. According to Dana smaltite occurs, but in small quantities, at the silver mines of Tres Puntas and elsewhere in Chili.

THE COBALT INDUSTRY

In the issue of July 1st, 1905, "Le Bulletin du Commerce," of New Caledonia, which during late years has been the country producing the greater part of the cobalt consumed, gives some interesting notes concerning the industry under the heading "Cobalt Canadien et Cobalt Calédonian."

Attention is drawn to the fact that Ontario is now a serious competitor in the cobalt market with New Caledonia and a synopsis is given of the paper, in the last report of the Bureau of Mines, on the Temiskaming Cobalt-Silver deposits.

The following is a rather free translation of a part of the article:

The governing powers of the colony (New Caledonia) have shown themselves in the last April session strongly opposed to the reduction of the export duty on minerals

Fig. 38. Forest fire on the east side of Cobalt Lake, opposite the railway station, June, 1905.

inaugurated in 1903. Since that time the condition of the cobalt market has been profoundly changed by the discovery of deposits in Ontario. New Caledonia cobalt no longer controls the market; as in the case of nickel, a strong competitor has arisen.

The Canadian, or rather American, oxide of cobalt is about to be placed on the European market. In March last, a meeting of those interested in the manufacture of cobalt oxide was held in Paris, and the Americans there proposed to furnish three-quarters of the world's consumption. The stocks of mineral or oxide to be delivered or in storage were then large. The manufacturers of oxide in France, England and Germany have restricted their purchases. It is this state of things which has resulted in the prolonged lowering of the market since the complete stoppage of the buying.

Another meeting of European and American manufacturers was announced for June. It will be interesting to know whether it was decided at this meeting that the

manufacturers of the two continents should work together or that they should enter into competition. In either case it means a reduction of our export if the Canadian cobalt is put to the same uses as our own.

It is then evident that the cobalt situation has radically changed and that it would be folly to willingly persist in the continuation of a tax, which while reasonable in 1903, will be disastrous in 1905, and will prevent all exploitation of deposits, especially those carrying low grade ore.

It may be added to this that it is difficult to see how any of the deposits of New Caledonia can be worked in competition with those of Ontario. The ores of this Province carry such high values in silver that they will be worked primarily for this metal, although they contain on the average much higher values in cobalt than do those of New Caledonia. Then there are the other by-products, nickel and arsenic in the Ontario ores. The ores of this Province should control absolutely the cobalt market.

In 1905, New Caledonia shipped the following number of tons of cobalt ore to the countries named, viz.: England 3,352, France 2,238, Australia 1,792, Germany 537, or a total of 7,919 tons, which is over 1,000 tons less than the shipments of 1904.

METALLURGY

The characteristics of the metal cobalt and its compounds are much like those of nickel and its compounds. The methods used for extracting one metal from its ores are similar to those used in the case of the other. Since these methods are complicated, an attempt will not be made to describe them. The reader, desirous of a knowledge of the methods, is referred to some standard work on metallurgy, such as that of Schnabel.

In former times cobalt glass, "blue color," was made directly from some of the purer ores carrying cobalt, nickel, silver and arsenic. Most of the arsenic was first roasted off, and to the residue were added the constituents of potash glass—powdered quartz and carbonate or other compound of potash. The roasted ore, with these constituents added, was then melted down, the cobalt uniting with the glass to form smalt and the nickel and silver settling to the bottom of the furnace. If a little arsenic was not left in the ore some of the nickel would also combine with the glass, thus injuring its color.

The blue glass, or smalt as it is called, was powdered and sieved, and was then ready for the market. An interesting account of this method of manufacturing smalt is given in Knapp's "Chemical Technology," first American edition, Vol. II, 1848.

Cobalt now comes on the market in the oxide form, the latest quotation being $1.60 per lb. for the pure oxide, CoO. There are seven or eight manufacturers of this oxide in Europe—three in England and two or three each in France and Germany. Little cobalt is used in the metallic form, owing to the fact that nickel serves practically the same purposes as metallic cobalt and is much lower in price. It is said that a little cobalt added to nickel in plating tends to produce a more silvery and less steel-like lustre. By far the largest consumers of cobalt are the potteries.

This Province is likely to soon have two or three plants working on the Temiskaming silver-cobalt ores. The International Nickel Company already has a plant in operation at Copper Cliff, Ont. Another company has secured the old Hoepfner or Frasch plant at Hamilton, and it is said a third company is likely to adapt the plant at Deloro, in Hastings county, which formerly was used in the treatment of the auriferous mispickel ores, to the refining of the Temiskaming minerals.

Appendix

THE EARLY HISTORY OF THE COBALT INDUSTRY IN SAXONY

Translated by G. R. MICKLE

"Is there anything whereof it may be said, See, this is new? it hath been already of old time which was before us."—Ecclesiastes.

Introduction

The following translation of portions of W. Bruchmueller's work (now unfortunately out of print) on the early history of cobalt mining and the manufacture of blue color in Saxony will perhaps interest those engaged in the cobalt industry to-day.[1] In the main the problems ahead of the miners of that metal at the present time are the same as they were over three hundred years ago.

The cobalt production marked a second period of mining activity in the district in question. The first was characterized by a feverish excitement and activity and a comparatively short life. Silver was the only metal sought at first and the veins were sometimes fabulously rich.[2] Two systems of veins were known—the silver with barite as gangue mineral and the cobalt veins with quartz.

The exact time when mining started in the cobalt region is not known, but the first important discovery of silver ore was made at Schneeberg in 1470, and the growth of the industry was phenomenal; by 1474 there were 176 producing mines. The most famous was the St. George at Schneeberg where veins of different formations joined and where one enormous block weighing 20 tons, described as 6 feet wide and 12 feet high, consisting of native silver, argentite, ruby silver and the chloride of silver was found. Records mention a banquet given underground by the Duke of Saxony using this block or nugget as a table.

Silver mining flourished for 25 years or more and then began to die down. Some of the veins had a length of about 2,500 feet and were followed in depth about 1,000 feet. These were, however, extreme limits.

In the case of the essentially cobalt veins (which carried some silver) there was an extraordinary massing or crowding together. In an area of less than four square miles 150 productive veins were found. After the invention of cobalt blue, mining flourished again.[3] It is with this second period of activity that Bruchmueller's work is concerned.

It is evident from the translation given below that an immense amount of searching into old archives was involved in the preparation of this work.

BEGINNING OF COBALT INDUSTRY

The beginning of cobalt mining and the knowledge of the use of cobalt in Saxony are wrapped in obscurity. The discoverer[3] of the blue color is said to have been a Frenchman, Peter Weidenhammer, who settled in Schneeberg in 1520 and made a blue color which he sold in Venice for 25 thalers[4] a hundredweight (112 lbs.). Christian Schurer

[1] Der Kobaltbergbau und die Blaufarbenwerke in Sachsen bis Zum Jahre i653 von W. Bruchmueller, 1897.
[2] Stelzner-Bergeat. Erzlagerstaetten.
[3] This was really a re-invention, as cobalt is said to have been used for staining glass in pre-historic times.
[4] Thaler about 75 cts.

is said to have improved the invention of the blue color. He had a glass works at Neudeck, and it is believed that there for the first time a blue color was made out of the cobalt from Schneeberg by fusing and the addition of pearl ash or potassium carbonate. It is said that this color was sent to Nueremberg and was there seen by the Dutch, who then went themselves to Neudeck and persuaded Schuerer to go with them to Madgeburg to make cobalt blue for them. Afterwards, when they had learnt Schuerer's secret, they sent him home again, where he started a small color mill. A hundredweight of this color at that time cost 7½ thalers. It sold in Holland for 50 or 60 gulden.[5] The Dutch are said to have immediately built eight color works and to have imported the necessary cobalt from Schneeberg. This blue color was made by taking the cobalt ore, in this case, smaltite, which contained some bismuth, and melting the bismuth out by gentle heating; then it was stamped and roasted in reverberatory furnaces. It was important that the roasting or oxidation should be as complete as possible. The result of this process was the cobalt oxide, known in the trade as safflor, a grayish brown powder. In order to make cobalt blue out of the oxide it is mixed with potassium carbonate (pearl ash) and white quartz and fused, then dipped out with iron spoons into a large vat, in which cold water runs continuously. By this means the blue colored glass attained its deep blue tint and became so brittle that it could be crushed and ground.[6] This crushed and ground material is then sifted, washed and finally graded through very fine sieves. By means of the washing the soluble constituents are removed, and the different colors known to the trade are produced, according to the fineness of the material.

We see, therefore, that in the beginning the production of the cobalt oxide in Schneeberg was not in the hands of large operators, but the small works treated their own cobalt and sold it to the dealers who came to Schneeberg. The oxide was then sent to foreign countries.

Cobalt Works in 1568

In the knowledge of the art of color-making they seem to have made rather rapid progress, for about the end of the sixteenth century they had begun to make the blue color themselves. The first one to make this was Christopher Stahl, who put up a little smelting works at Schneeberg in 1568, also some mills, melting furnaces and color works, in which he made a blue color for artists. Nothing is known about the extent of his works, but it could not have been great, as Stahl's undertaking is only mentioned incidentally, and the production of colors for artists could naturally not be carried out on a large scale. These works did not last long. They were swept away by a flood in 1573. After Stahl's death an attempt was made to carry on the color trade on a larger scale, and according to the spirit of the times, this undertaking must first be protected against competition by a decree on the part of the State, but in spite of the energy and business ability and large capital of the two engaged in the undertaking, it failed The two in question were Hans Harrer and Hans Jenitz. They went to the Prince in 1575 requesting a concession to erect a color works and to allow them the exclusive right for ten years to purchase cobalt ore in Schneeberg. They stated that they had noticed for fourteen years how the oxide which was prepared in Schneeberg and the vicinity was bought up by agents of foreign merchants and sent out of the country to Nuremberg and from there to Italy and Venice and other places. Out of this oxide blue color was made and sold at a high price. By means of laborious experiments and at a large expense they had arrived at the secret of the preparation of the blue color and they were now willing to put up a works, but they were afraid that very soon others would be engaged in the preparation of colors and therefore they requested the concession mentioned above. Stahl's works were not mentioned by them at all, and from this we see that his plant cannot have been large.

[5] Gulden = about 45 cts.
[6] The blue color or smalt usually contains about 6% cobalt.

First Monopoly Granted in 1575

This concession was granted them by Prince August in 1575. According to it Harrer and Jenitz could erect the color works and they alone had the privilege for the next ten years to buy cobalt oxide in Schneeberg, and they could work it up and deal with it as they wished. They had to pay, however, the cobalt mines the same price which they had got for the ores from the foreign dealers. No one during these ten years could engage in the preparation of color without their consent, neither could he buy the ore or the oxide and ship it out of the country.

This undertaking, however, did not fulfil the expectations placed upon it. Schneeberg was, of course, the principal place of production for the oxide, which, as before, was chiefly prepared by the works themselves, and then sold to Harrer and Jenitz. The color exchange was in Dresden, but in spite of numerous efforts, the disposal of the colors presented great difficulties. Moreover, contrary to the royal concession many engaged in the preparation of color in Schneeberg, and bought up the oxide and sold to competitors in Nuremberg, who probably also worked up Bohemian cobalt and brought it on the market. A letter of this period, namely, 1579, from Hans Harrer to foreign merchants shows us the state of affairs and how Harrer exerted himself to find a market for his product. Harrer complaims that he had spent a great deal of money for the purchase of the oxide and the preparation of the color, but in spite of all that he could not find a market for it. He could only deal in the matter at a loss. Not long before, he stated, he had sent some of his color to Lisbon, but the merchants there had done very little with it and finally it was left unsold. He (Harrer) had quite a stock on hand which he wanted to get rid of, and he therefore asks for the addresses of those to whom he might send it.

Troubles of the Cobalt Buyers

In 1579 Harrer & Jenitz complained to the Prince. They stated that in spite of the concession which had been granted them there were about twenty others in Schneeberg who were engaged in buying up cobalt and making it into color, and that these others were putting everything into barrels, whether it was good or bad, and trying to sell it for good color, and therefore it had come to this that during the four years of their monopoly they had put several thousand gulden into the undertaking, and had not been able to sell most of the color or oxide which they had prepared. Moreover, several of the inhabitants of Schneeberg, contrary to their concession, had demanded a higher price for their oxide, and when this was not granted they had taken the color out secretly at night and even sometimes had packed it out openly on their backs. Harrer and Jenitz therfore begged for a renewal of their monopoly and an extension for four years more, and a sharper decree against the smuggling of cobalt and cobalt oxide.

The Prince granted this request and renewed the concession till 1589, according to it the contractors alone had the right to buy bismuth and cobalt and the oxide. The works might, it is true, work up their cobalt ore themselves to oxide, but then they must sell it to Harrar & Jenitz for 10 groschen[7] a hundredweight. Selling to others would be punished with a fine of 200 thalers and confiscation of the goods, which would belong to Harrer & Jenitz. In spite of this decree the undertaking was not a success, and after the death of Jenitz in 1589 (Harrar had died in 1580) and the expiry of the concession in the same year, it was not renewed, so that the first attempt to organize the Schneeberg cobalt and color trade and to make the blue color in Saxony themselves, was a failure.

Change in Industrial Conditions

About this time there was a change in the political organization of the country. Every undertaking of any size required a concession from the Prince, just as we saw

[7] Groschen = about $2\frac{1}{2}$c.

in the case of mining, and the ideas of the rights of the Princes gradually changed. These conditions made their influence felt on the cobalt mining of Schneeberg, and rendered it possible to bring in considerable amounts of foreign capital, because the Princes, who were at this time, almost always in need of money, gave concessions for the exploiting of their mining privileges in consideration of certain loans from foreign traders. This was acceptable to the foreign traders, as they had thereby the only security for their money.

Stealing of Ore in 1603

In the year 1603 we hear for the first time of a more strict supervision on the part of the Prince over the production of oxide. In this year the mining office complained to the Prince that there were people in Schneeberg who were engaged in making the oxide, but did not have any cobalt or bismuth mines. The Prince decreed, therefore, that for the future no one should be allowed to buy cobalt or bismuth or sell it before it had been accepted by the mining office and determined whether it came fresh from the mine or had been taken from some dump.

Export Tax

Shortly after this also the Prince put a tax on the Dutch merchants for the cobalt that was bought in Schneeberg, and ordered a strict supervision of the export. In the decree in question it was stated that merchants from Holland in the last quarter of the year had bought over four thousand hundredweight of oxide in order to take it to Holland, England and Spain—from this the Prince did not receive any taxes. Out of the tax of one-twentieh very little came in, and from this the Prince had always to keep the principal adits in order and therefore for every cask of oxide that was sold a gulden must be paid as tax. This tax would fall on the foreigner, and they would not evade it because they had a good market for their wares; all colors, for the purpose of collecting this tax, must be weighed by an official in Schneeberg, and recorded. Any evasion of the tax would be punished with a fine of 500 florins, and confiscation of the goods. Every cask must be printed with a certain mark, and all casks without this mark were to be expropriated. In the same year one Berckau from Joachimsthal came to the Prince with a proposition that the Prince should take the sale of the color into his own hands, as according to Berckau every year great quantities of color and cobalt were sent from Schneeberg to Hamburg and Holland, and from this the Prince only received a very small tribute, but everything for the manufacture of color was found in Saxony, and he, Berckau would guarantee to make good color glass out of the Schneeberg cobalt for half the price which it cost them in Holland and Hamburg. Moreover he said the Hollanders would far rather buy the glass than the raw oxide. If the Prince would take the sale of the color in his own hands he and an associate would take charge of it and produce yearly two to three thousand hundredweight of color glass. He gave two calculations as to the cost of color in Saxony and Holland as a basis for his proposition. The calculation as to the cost in Saxony was as follows:

	Florins.
100 cwt. of unstamped cobalt ore cost	300
Wood for roasting	9
Two workmen for 14 days	9
Loss 3 cwt.	9

therefore 100 cwt. as exported from here cost 327 florins, and add to this

	Florins.
50 cwt. flux	400
Wood to melt	42
4 workmen for the melting for four weeks at the rate of 2 florins per week per man	36
Other expenses	25

or a total of 830 florins for 100 cwt. He calculated in the same way the cost in Holland at 1,000 florins. Now as a hundredweight sold in Hamburg for 20 florins, therefore the profit was 100 per cent. The Prince should give him an advance of 5,000 florins for his works and they would take charge of it, but they must first take a trip to Holland and England in order to make contracts with the dealers for large amounts. As remuneration they asked 20 per cent. of the profits. The Prince did not consent to this proposition of Berckau's. The result of this proposition and consultations was the royal decree of 1609, in which it was made known that for the future the Prince would buy up all the cobalt made in Schneeberg, which was formerly taken by foreign merchants end sent out of the land. The purchase was to be made through the tithe collector. The works producing cobalt were directcd not to sell their cobalt to any one else under a penalty of 500 florins, and all the dealers were forbidden under the same penalty to buy cobalt without the consent of the Prince, or to dispose of their stock on hand either in or outside of the country. The Schneeberg cobalt trade thus became a State undertaking.

SCHNEEBERG COBALT AND OXIDE TRADE AS A STATE UNDERTAKING

The first consequences of the change of the Schneeberg cobalt and oxide trade into a purely State undertaking were decidedy favorable. The stricter organization, and the greater capital which the new management could command, led in the first place to a rise in the price and increase of the sale. This operated in favor of the cobalt miners, even although it must always be kept in mind the money bags of the rulers profited by the change. In the course of time, however, the financial difficulties under which the Princes at that time almost always labored exercised a baneful influence. Their interests were always more and more put in the foreground, and they were willing to let the works get under control of capitalists who were able to make large loans. These concessions would be given for a period of years. It must, however, be acknowledged that, as a last resort, the mining office stepped in on behalf of the cobalt miners and the Prince generally followed the advice of these officials and remedied the most crying evils. Moreover, the terrible industrial crisis began to make its influence felt. This was brought about by the practice of clipping coins and by the Thirty Years' War. These circumstances led to a complete ruin of the Schneeberg cobalt mining and the oxide trade about the period of 1620-30. We will look into these circumstances more in detail shortly, but must first notice the organization of the cobalt and oxide trade as it existed after the conversion of the industry into a purely State undertaking.

Ordinance of 1609

According to the ordinance of the Prince in 1609, the tithe-collector in Schneeberg had to take over all the buying and selling of cobalt and oxide. The first task was to find a buyer for the cobalt purchased from the works and the dealer, Kreifinger, applied to the Prince for a fixed contract. The following agreement was made with him in 1610. It was for a period of six years: All oxide colors which were produced during these six years in Schneeberg and were of good quality were turned over to Kreifinger. He had the power to sell his oxide wherever he wished, but he must first supply the business houses of the Principality with these wares. Kreifinger had two Leipzig merchants as guarantors. The price per hundredweight was six gulden and ten groschen and notice had to be given half a year before expiry of the contract. Kreifinger had to advance the Prince 3,000 florins, and he was to receive back 500 florins per year and the interest. Some alterations were made in this contract afterwards to the effect that the oxide was divided into two classes. These changes were in consequence of complaints on the part of the contractors. They objected especially to the fact that all the oxide that was produced in Schneeberg should be accepted by them, and therefore every year fixed amounts were agreed on. The whole management of this business was left to the tithe-

collector. He had to look after the purchase and taxing of all the cobalt ore delivered by the works, then deliver them to the contractors and carry out all the bookkeeping. There were numerous complaints on the part of the works that the tithe-collector estimated their cobalt too low. The bucket of cobalt ore was paid for at the rate of two to three florins, and the hundredweight of oxide three to four florins. This task soon became too great for the tithe-collector. He therefore requested assistance in his work, and a couple of officials were allotted to him. These two officials were to inspect and estimate the cobalt in the presence of the tithe-collector and agents of the contractors, to look after the roasting of the ore, visit the stamp mills weekly, weigh out the color for the dealers, and keep strict account of all color that was made.

An attempt was made to induce the Prince to cancel the contract with Kreifinger. He was accused of being a swindler, who had already been in jail. At the same time proposals were made to make the color in Saxony. In spite of these objections the Prince stood by the contract, and even renewed it for six years more. According to this later contract the Prince had to deliver yearly 3,500 hundredweight of oxide, 3,000 at 8 florins and 500 of inferior quality at 6 florins. Kreifinger, in consideration of this, made the Prince a further loan of 4,000 florins. These advances on the part of the contractors to the Prince were characteristic of all the concessions.

Troubles of the Miners

A few years after this, namely, in 1616, the cobalt miners petitioned for a remission of the tax on the ore and for a higher price for their cobalt, as mining was getting more expensive all the time, and the ore scarcer, and prices for necessary articles were always rising. The tithe-collector suggested an increase of half a florin on the bucket.

In 1617 the following ordinance was made:

1. All the cobalt ore must be inspected by the officials before it is rated and taken to the ore house in order to determine from which mine it came and to see whether good and inferior ore were not mixed together. For this inspection the mines had to pay each time two groschen. The previous taxes were maintained.

2. No robbing of the mine was to be practised.

3. No miner was to go underground more than two shifts in the day.

4. All the cobalt purchased from the works was to be kept separate and roasted by itself in order that the tithe-collector and the superintendent of the cobalt could settle correctly with the different works, and in order that the cullings-out could be replaced by the different works.

5. The assayer had to take a sample from each cask of oxide and this was to be kept in the office.

6. No cobalt ore was to be stamped either by night or on holidays.

7. Two buckets were to be kept and filled with ore by the works, one of which the tithe collector was to receive and the other the mining office.

8. The officials had to inspect the color works weekly, and the ore-dressing plants, and no one had any right to enter the stamp mills without permission.

9. Every cask of color was to be weighed and stamped with the Prince's trade mark. The color was to be sold by the hundredweight to the merchants in Holland.

Unfortunately, however, these rules were not observed, and we see that shortly afterwards the works were complaining over the tithe-collector, Roehling's, practice of culling out. The cobalt that was delivered by the works was not kept separate, they stated, but all mixed together, and then the works were compelled often to replace more ore that was culled out than they had sent in the first place—for instance, one mine which had delivered 53 buckets of cobalt was ordered to replace 64 buckets, and moreover they said this ostensibly culled ore, which was often better than the cobalt that was accepted, was not sent back to them, but was taken sixty miles and farther sometimes—they would like to know why. They said that the tithe collector was always in debt to the works, so that they were compelled, in order to carry on their mines,

to borrow capital at high rates of interest. Therefore they requested that Roehling be ordered to cull out the ore from each work separately, and to give back what was culled out in order that they could pay off their workmen properly, and they also asked that the tithe-collector should pay them in full every half year, or if not, that the Prince should allow the works, after this contract was run out, to work up their cobalt to oxide themselves and sell it as they might. . They offered to give the Prince, if the tax of one-twentieth was repealed, for every hundredweight of oxide one florin. They stated this would bring in more than came from the contracts now. The Prince promised to look into the matter of the excessive culling by the tithe collector, and to give them an answer about this open dealing after the contract expired. In the same year the works made another complaint about their being in arrears with their payments. They stated that they were no longer in a position to pay their workmen, and they had to keep on borrowing money at high rates of interest.

Coin Clippers Period

We come now to the time of the Thirty Years' War and to the general money crisis in Germany, which is known as the time of the Coin Clippers. The consequences of the war were noticed in Schneeberg after a few years, but the tremendous money crisis was felt at once. In Germany for some time there had been excessive clipping of coins going on, and in consquence of this currency of full value was vanishing, and the country was flooded with depreciated money, thereby bringing about a tremendous increase in the price of all articles. This money crisis was all the worse because it coincided with the Thirty Years' War, by which trade was crippled everywhere. In consequence of these two circumstances the production fell greatly, from over 8,000 buckets in 1620 to about 2,000 in 1639.

The cobalt miners regarded the contract which the Prince had forced on them as the sole cause of their desperate position. They were no more able to recognize the true cause of the industrial crisis than their contemporaries. Their object, therefore, was to have this contract cancelled and to obtain unrestricted trading in their cobalt and oxide without the intervention of the tithe office and foreign dealers. They therefore asked in 1619 for the granting of open dealing in cobalt, and the Prince told them that after the contract ran out in 1620 he would give them an answer. The Prince was, on his part, too much dependent on the support of these foreign dealers, as it was only with their large capital that he was able to undertake the extensive business involved, and the contractors, on their part, were quite content to have the concession as a guarantee for their debt. He therefore could not entertain the wishes of the miners.

The Prince renewed the contract with the Dutch for six years, but it was finally cancelled, as the contractors only wished to take yearly 3,500 hundredweight as before, while the Prince demanded the purchase of a larger quantity. In spite of this the Prince would not grant open dealing, but made another contract with some Leipzig merchants and others. The contract was for twelve years. The Prince agreed to deliver them yearly 6,000 hundredweight, and the contractors could deal with these either at home or in foreign markets, but they must first supply the dealers of Saxony. If the contractors could not get rid of the color afterwards they could keep it in Schneeberg in some of the offices, and in the meantime no one else should be allowed to deal in color, and the Prince would give a patent against cobalt smuggling. On their side the contractors must agree to take the 6,000 hundredweight yearly, even if war broke out, and stopped trade, and they must pay in cash 5,000 cwts. at 8 florins, and 1,000 cwt. of inferior quality at 6 florins. Payment must be made in good French money.

Loans from Contractors to Prince

In the autumn of that same year the Prince applied to the contractors for a large loan. He explained to them that he required 50,000 florins for a very important

matter, and requested them to advance this money. They declared that is was at the moment impossible for them, but they would manage to do it in the course of six weeks, advancing the money at seven per cent. Some time afterwards they said that they were ready to advance the 50,000 florins if the oxide trade and the purchase of the cobalt was made hereditary and irrevocable to them, and that they should buy the cobalt by their own agents and work it up to oxide themselves without the royal tithe-collector having anything at all to do with it. For this privilege they would pay the Prince 4,000 gulden yearly. The Prince agreed to this unheard-of demand without hesitation. The contractors were to make the payment and the tithe-collector to be notified of the fact.

Intervention of Mining Office

This doubtful step was not carried out however, as the mining office took a hand in the affair and explained to the Prince that this proposal was contrary to all mining rights; that the miners would leave, and then he would lose the 4,000 florins which he got from the contractors, while the cobalt mining had brought in the Prince yearly up to the present time about 6,000 florins. This concession was never formally withdrawn. but is never mentioned again, and matters remained as they were, the contractors lending the Prince 17,000 florins, which the Prince set down to the credit of the works. In the next year the works sent an urgent request to the Prince to pay them for their cobalt that was delivered, that there was 17,000 florins overdue from the tithe-collector, and they further asked for payment in good coin of the land, and not in copper coins from Brunswick, which they could not get rid of. They stated that all necessities and appliances were advancing at a terrible rate, the price being about three times what it was before, so that a great many had to leave on account of the expensive living, and finally they expressed a desire for open dealing again, and requested an extra payment for the cobalt. The mining officials agreed, or gave a favorable report on this petition. and suggested that they be repaid the 17,000 florins and get half a florin more per bucket for their ore. This was done by the Prince. The contractors, on the other hand, were not by any means satisfied. They had expected a greater profit for their undertaking than it really gave, and they complained continually about cobalt smuggling, further, they objected to the tithe-collector at Schneeberg,—that he delivered them oxide that was no good. The Prince therefore ordered a strict inspection by the mining office, as these complaints had become too frequent. The remonstrances, however, continued till finally the Prince ordered an investigation. In consequence of this investigation the Prince took away the control of the outside works entirely from the tithe-collector, and put them in charge of a new officer. This concession did not satisfy the contractors: in the meantime, in order to get rid of the contract. they had made an agreement with one Brandenstein, and in consequence of this they stated that they had everywhere found opposition, and reverses with their contract, and they feared great loss, if not complete ruin. Therefore they requested the Prince to hand over their contract to Carl Brandenstein.

The Prince was heavily in debt to Brandenstein, who was a money-lender of the worst kind. He had lent 22,000 florins of depreciated money to the tithe office. and probably he expected to recoup himself with the oxide trade of Schneeberg. He did not succeed in this, however, as his inconsiderate treatment of the miners overshot the mark, so that he had to abandon the contracts. He had asked the Prince for the most complete and untrammelled powers in the direction of the business for twelve years. According to the contract Brandenstein would take over the purchase and the preparation of oxide. All the directors of the color works and all the employees of the Prince. except the mining officials in the mining office and tax collectors were to be put under the direction of Brandenstein. and he had the power to dismiss them or fill their places. after notifying the mining office. The new officials would then be engaged by the Prince and turned over to Brandenstein, who was to pay their salary. The cobalt ore was

to be paid only in good coin, but the works had to deliver good pure material. Material that was worth less than 3 florins need not be paid for at all. Any ore that was not good would be put aside and could not be sold. All good cobalt Brandenstein was forced to accept, but he need not pay for it at a higher rate than five florins, and he must pay in good coin. All the color works and stamp works which were in bad repair Brandenstein was to take over and he would be recouped for the expense of repair after the expiry of the contract. He was to receive wood out of the Prince's forest at the usual price and in addition to the stamp work he might build a new cobalt works, the cost of which would be refunded to him. He should have the stamp works belonging to the tithe office as long as he wished for one gulden weekly rent; in consideration of his previous advances the whole stock of oxide, etc., and 16,900 buckets of cobalt were handed over to him. He could make this up to color and sell it wherever he wished, and in consideration of this he had to pay the works the money that was due, but they had to first replace the ore that had been culled out with good cobalt. After the expiry of the contract Brandenstein or his heirs had a prior right to a renewal of the contract. If the supply of cobalt ore failed the contract would be cancelled and Brandenstein had to see that the various taxes were all paid.

Disputes Between Miners and Contractors

We see that by this means the Prince had handed over the trade in oxide, which had been very profitable to the Treasury, to Brandenstein for a period of twelve years without any further consideration except that the Prince was free from the responsibility of paying his debts to the works. Immediately after the signing of this contract a bitter quarrel began between Brandenstein and the works. They demanded payment of the balance of over 30,000 florins which was due them for cobalt which they had delivered. Brandenstein put every obstacle in the way; he demanded the replacing of the ore which was culled out, and stated that the stock on hand was a great deal smaller than was represented to him at the time when the contract was made. The works, on their part, objected to the excessive culling. They would have to close down their mines and send off all their men, who already lived in the most wretched state of poverty. They stated some were even dying of hunger. Their creditors were threatening to evict them from their mines, and the adit was in danger of caving in, as they had no means to keep it in order, and furthermore they complained especially about a wilful underrating of their cobalt and of the low price. In spite of the efforts of the higher officials of the office to induce Brandenstein to accept some of the lower grade cobalt and to pay up the outstanding amounts to the works, he obstinately stuck by the letter of the contract, and complained that he was losing by it. The works did not let the matter rest. In spite of a sharp notice from the Prince about their inopportune grumbling they continued to send in complaint after complaint, always about the same points, and with the same conclusion, namely, that they should be allowed open dealing for their cobalt. Brandenstein finally gave way to this uproar raised by the works, which was backed up in the most essential points by the officials in the mining office. He therefore voluntarily cancelled his contract with the Prince and the Prince gave permission to the works to make up their cobalt to oxide themselves, and to deal with it as they wished, but they had to pay the regular taxes, and in addition to that one florin for every bucket of cobalt made up to oxide. Smuggling in cobalt would be punished by a fine of 500 gulden

Open Dealing Not a Success

The cobalt works had reached the desired goal, and they hoped that with that all their difficulties would be at an end. But very soon the opposite became evident, and although the management of the State might have been a great deal to blame for what had happened in the last few years, it was not the only reason for the decline of the Schneeberg cobalt mining. It was rather dependent on the general industrial and political crisis under which all trade and industry languished, and the general pur-

chasing power of the public greatly diminished. This was especially noticeable in an article which was not absolutely necessary, such as the color, and in times like this it was the small works and those with less capital which necessarily suffered most. We hear, therefore, a few weeks after open dealing had been allowed, strong complaints on the part of the works. They stated that in addition to the tax they should not be required to pay one florin for every bucket of cobalt,—that Brandenstein had ruined the whole business, and no human being was willing to buy any color from them. The cost of mining a bucket of cobalt was two or three florins, and if the expenses were so great they would have to discharge their miners, and therefore the Prince should remit the one florin on the bucket of cobalt. The Prince granted this request in part, and an inspection was ordered of all the works by the tithe-collector, and that the adits should be kept in repair where there was any danger of a cave-in or other damage, and they were further to see that the barren rock did not remain in the adit, but should be brought out to the surface. For the purpose of collecting a tax they should inspect all the mines which were producing every two to four weeks, and be present when some of the ore was hoisted, and should cull the cobalt in proper manner and measure it up. The works were not satisfied with this. The Prince pointed out that the office, the mining officials and the works had made representations about excessive taxation, and that the works had said they were ready to pay these taxes if they got open dealing, and that they stated they would find enough buyers who would take their cobalt at ten florins which they were forced to sell at five. Now they said the very opposite. They were to blame themselves. In spite of this he said that he was willing in the future to take the tax of one florin a bucket and remit the mining taxes.

As soon as an opportunity offered the Prince made one more effort to close a new contract. Two men offered to negotiate; one was the merchant, Hans Friese, and the other was from Frankfort, Daniel de Briers. Both declared that they had bought a great quantity of oxide, but the business had not succeeded, as in the previous years a great deal of very bad material had been made, still they were willing to go on with the venture if a monopoly was given for from one to three years. The Prince seized this opportunity immediately and made a contract without consulting the Schneeberg cobalt works. It was for six years. According to this the two contractors were to take yearly from Schneeberg and Neustadtlein 3,000 buckets of cobalt. The payment should be made according to four grades. The No. 4 grade was to be considered as absolutely worthless, and the first three grades were to be paid respectively with 3, 2½ and 1¼ reichstaler. The samples were to be kept in Schneeberg and the cobalt was to be taxed according to them. The cobalt, as soon as it was taxed, was to be delivered to the two contractors, who could make oxide of it and deal with it at home or abroad, as they liked. The payment for cobalt was to be made to the works immediately by the contractors in cash without any deductions, that is, neither the Prince nor the tithe office had anything to do with it as formerly. The latter had nothing more to do with the trade, but merely inspected it through the mining office. Moreover, the contractors were to take the cobalt ore which was paid in to the Prince as mining taxes by the works, and also that which was mined in his own mines, at the price of 3 florins a bucket. At first the contractors were not to export their cobalt and oxide from Schneeberg, in order that the business might recover its reputation again, and all dealing in oxide and cobalt was strictly forbidden to all other persons during this period of six years, but in consideration of this the contractors were bound to take yearly 3,000 buckets, even if war broke out and stopped trade, and if more than 3,000 buckets were mined in one year the excess would be kept for the next year. For this privilege the contractors were to pay yearly 1,000 thalers into the Prince's exchequer, making it in two equal payments, and also pay rent for the works belonging to the Prince which they took over. If the contractors, after the six years, did not wish to renew the contract, they must give a half-year's notice; on the other hand, if they wished to go on they would have the refusal over others.

Contract versus Open Dealing

This contract was submitted to the works, who immediately opposed it, as they declared that it would mean the certain ruin of the whole mining industry. They straightway came to the Prince with a petition about the contract, and to request the retention of open dealing, and they especially complained of the small quantity of cobalt which was to be bought, namely, 3,000 buckets, and of the low price, stating that, under these conditions, they were doomed. They begged, therefore, to have the contract cancelled, and to stick to open dealing. They promised to pay the tax most punctually, and to abstain from any smuggling on their part. In order to meet the works somewhat in this respect the two contractors stated in writing that although they were not, under the existing circumstances, in a position to take more than 3,000 buckets, nor to pay any more for it, they would be willing, if the conditions improved to buy a greater quantity of cobalt and pay a little higher price. This declaration on the part of the contractors, which was not really of any value, did not remove the opposition of the works, but it had the effect that the works now divided into two parties,—one which declared that they would like the contract provided there was a greater quantity bought, and the price were a little higher, while the other party still opposed the contract. The party which was irreconcilably oposed to the contract persisted that if they got open dealing they would give the Prince, instead of the tax of one-twentieth, every tenth bucket, while the other party stated that this offer could not be acceped, and wished for a fixed contract, however, with the conditions mentioned above. Negotiations in this matter dragged on for some time. The contractors finally agreed to take 4,000 buckets annually, but stated that an increase in the price was impossible at present. The mining office stated that the prices offered to the works by the contractors were not reasonable, as the costs in mining were too high. However, offers and counter-offers were made, and as a final result the Prince asked for a vote from the works of "contract" or "open dealing." All the works which were producing ore must state in writing whether they were for a contract or for open dealing. The result was that 30 persons, representing 87 mines, voted for the contract, and 43 persons, representing 132 mines, voted for the open dealing. In consequence of this majority for open dealing the Prince decreed that the contract was cancelled and permitted open dealing again, with the condition that every tenth bucket of good pure cobbed cobalt ore should be paid into the Treasury, and in addition to this some other taxes, which could be paid in money or cobalt. Those of the works which had received advances from the contractors, or had ore to their credit, should settle the matter with them.

Crisis in the Industry and Effect of War

We come now to the saddest time for Schneeberg cobalt mining. In 1629 the works requested, instead of every tenth bucket, that they should give every twentieth, as they could not get ready cash for their cobalt no matter how cheap they were willing to sell it. This request was repeated in 1632, and at the same time they petitioned for the establishment again of a fixed contract. This, however, considering the bad position of all commercial and political matters, was an impossibility, especially as all the foreign contractors had had bad experiences with their contracts, and were not willing to bind themselves for any length of time. A good idea is given of the conditions and the position of the Schneeberg cobalt mining at this time in a report of the chief official of the mining office in the year 1631. According to him the works since about 1628 had found almost no sale for their oxide, because the Dutch had withdrawn entirely from this trade, and they were the ones that had bought up most of the oxide before. Moreover, the war had been spreading all the time, so that all the passes in the mountains were guarded, and all trade was blocked. The works had sought to sell their goods themselves, but they had to dispose of them at a very low price, and at a loss. Sometimes they were not paid for in cash, but in goods, which they could not sell again

without a loss, and they had been compelled to pay their workmen in the mines with cobalt, which they had to sell dirt cheap in Bohemia in order not to die of hunger. It was true that a decree had been made that the workmen were to be paid with money, but there was so little of it in the country that they were afraid that if this decree was observed the mining must be stopped altogether. In addition to this misfortune it seems that about this time Schneeberg suffered directly in the war. In 1632 the Croatians swept down on Schneeberg, took the town and sacked it and ruined many of the mines. At that time the population of Schneeberg was only about 2,000, whereas it had been over 3,000 in the year 1600. In consequence of the lack of money they had neglected to carry on the necesasry repairs in the adits, and as a result many of the mines were flooded. The deepest adit caved in about that time, and they were not able to mine any more in consequence of an inrush of water, and the production of cobalt fell off. It is believed that shortly after this there was not a single mine in Schneeberg which made any profit, as at the very most they could only get about 25 groschen for a bucket of ore, while the mining of it cost a florin or more, and in addition to that they had to pay some tax. The only exceptions to this were three mines, which made a little because they had some bismuth.

THE PROSPEROUS TIME FOR THE SAXON BLUE COLOR WORKS

After the year 1628, instead of a fixed contract the cobalt works were allowed to deal with their ore as they wished, without improving the position of affairs at all. We have seen, moreover, that the conditions for mining just at this very time were exceptionally bad. The production of the mines had sunk considerably, and did not begin to increase until after the forties. This was brought about, as we saw, by the depreciation of the coinage. That and the blocking of all trade with foreign countries because of the war, and the other devastations which the war brought with it, had brought the Schneeberg mining into a desperate state, from which there did not seem to be any escape. This unfortunate period had caused most of the works to see that their position was better under the cobalt contracts which they had fought so hard against, even although they did not receive the principal advantage themselves, which went rather to the contractors, because when they had open dealing and the times were uncertain the works which lacked capital depended altogether on foreign dealers. Moreover the worst of the storm of war was past. It is true that in 1642 Schneeberg was sacked again by the Swedes, but on the whole more peaceful times were dawning, and moreover the cobalt mines had been producing better ore for some time. As the result of all these causes a gradual wish began to be expressed for a general contract and the establishment of color works in Saxony, a plan which, if successful, would probably give cobalt mining a sounder foundation than the sale of cobalt and oxide to foreign dealers. Some offers were made by different parties which were not acecpted, as there was no guarantee that they would be able to carry out the contracts, and after some considerable discussion and negotiation the Prince summoned the principal officials of the mining office, the civic officials and whatever contractors were willing to bid, to meet together and lay their proposals before him, to see if they could make a contract by which the works could sell a fixed amount of good, medium and low-grade cobalt, the payment to be in cash, according to the assays of the ore. The small works, too, which could only mine a little cobalt, were to receive consideration, and moreover all the wages were to be paid in money, and not with color or cobalt. The sale of cobalt to Joachimsthal in Bohemia was to be absolutely forbidden, and if they did not succeed in closing a contract the Prince was to receive a report as to how far they advanced, together with advice as to what should be done in the meantime. Before these officials had finished the task set them by the Prince an advance was made towards this goal from another quarter. In March, 1641, the Hamburg dealer, Hans Friese, made a private contract with six of the cobalt mines in Schneeberg. This agreement was filed in the mining office, and it contained express provision that the contract should be cancelled immediately the

Prince succeeded in making a new one. The substance of it was as follows: Friese was to take from the works in question for three years 300 cwt. of cobalt, and was to pay them in cash immediately on delivery at the rate of two thalers and six groschen; the works could receive a part of their payment from Friese in goods and should the works mine more cobalt, this excess was to be offered to Friese first, and if he did not wish to take it they could sell it in any way they liked. The cobalt should be pure and thoroughly cobbed out, without any hornstone, slate or pyrites. The first delivery was to be made at Easter, 1641, and then every six weeks following—smaller contracts were made by others with different mines. In the meantime the officials who had been commissioned by the Prince to make a contract had not been successful. This was due chiefly to the opposition of Hans Burkhardt, and therefore the mining office ordered that a temporary contract should be made, and for this temporary contract Hans Friese and Schnorr made a bid. Schnorr, had, a short time before that, built a small color mill, and wished to work up the Schneeberg cobalt there, and he stated that he was willing to contract for a year on condition that during this time no blue color work should be built in Saxony. This contract was actually agreed on between these two and twenty-three of the works. In consequence of this further development of matters, Burkhardt gave up his former opposition and declared that he was willing to take part in the contract on condition that he should receive permission to erect a blue color works. The only opposition now was from Röhling, one of the contractors. He said that he had made a former contract with some of the Dutch, which he must adhere to, as the Dutch dealers had made him an advance, and if he cancelled the contract the money would have to be refunded. After his contract had lapsed he said he would be willing to join. The mining office, however, believed that it was not necessary to pay any attention to him, as his contract with the Dutch dealers was not recorded in the mining office, and was therefore not binding.

Local Customs Works, 1642

As a result of the conference, lasting several days, between the Prince and three of the contractors, namely, Friese, Schnorr and Burkhardt, an agreement was made which embraced all the Schneeberg works. It contained the following points: The agreement was between all the works which existed at Schneeberg and Neustadtlein and the contractors Hans Burkhardt, Hans Schnorr and Hans Friese, and made with each of the three individually and not jointly, for a period of six years. The three contractors above-mentioned were to take from all the works, including the Prince's and their own, yearly a quantity of 2,400 hundredweight, and they were to pay according to samples which were to be kept in the mining office. The payment was to be in good money and at the rate of 3 thalers 18 groschen per hundredweight for No. 1 grade, 2 thalers 18 gros. for No. 2, and 2 thalers for No. 3. Cobalt ore which was better than these three grades or not equal to it, should be paid by the contractors according to the decision of the mining office. Each of the contractors was to take 800 hundredweight. The mines, on their part, were required under penalty of a heavy fine, to refrain from dealing in cobalt or oxide with any one else during the period of this contract. If one of the contractors should die his heirs would be bound to carry on the contract until it expired. Friese had permission to export his cobalt, Burkhardt was allowed to build a color mill in Saxony, and Schnorr was to be also allowed to build one there and work up his cobalt. The agreement was finally confirmed by the Prince in 1642, and a decree was made against cobalt smuggling. In this decree every sale of cobalt in violation of the agreement, especially the sale into Bohemia, was to be punished by a fine of 500 florins, and if the fine could not be paid, corporal punishment would be substituted. The informant would receive one half of the goods which were confiscated and the other half would be used for maintenance of the adit in Schneeberg. In accordance with the royal permission, Hans Burkhardt settled in Oberschlema, near Schneeberg, where he had picked

out a site for his color mill. It is true there was some opposition from the town council of Schneeberg, which regarded this as an encroachment on their rights and jurisdiction, but on account of the concession granted by the Prince it was allowed to stand.

This new contract soon met with difficulties which endangered its permanence. At the very outset the works and the contractors were in dispute about the assessing of the cobalt according to the assays that were made. The contractors complained that the mining office assessed the samples which were better than No. 1 too high, and that they had introduced intermediate payments. The Prince decided that these intermediate valuations should not be used, and threatened with severe punishment those who did not obey. The samples which were better than No. 1 should be graded as No. 1, and those which were better than No. 2 but not quite so good as No. 1, should be graded as No. 1. If the differences were much greater, then they were to be paid according to the next-lowest grade, and all ore which was not up to No. 3 grade need not be paid for at all by the contractors. The works were advised that by care they would almost always reach that grade. The Prince also warned them that they must keep the contract or they would not find any one to buy their cobalt.

A more serious danger threatened the industry in the following year. This was due to the death of Hans Friese. According to the terms of the contract his heirs were bound to carry it on, and as a matter of fact his widow tried this, but on account of lack of capital she was unable to carry out her obligations, and finally one of the principal creditors, Oehme of Leipzig, took over Friese's contract. A few years later, in 1647, after the expiry of the contract, which was made in 1641, all the success that had been achieved hitherto was jeopardized. Burkhardt refused most positively to make a new contract, even although the Prince threatened him if he persisted in his refusal to cancel his right to have blue color works, but Schnorr and Oehme stated that without Burkhadt's assistance they were not in a position to buy all the cobalt from all the mines, and they would therefore make provisional contracts with individual works. The works on their side, were not satisfied with that, and requested again for permission to have open dealing, as they could not get any other contractors. The Prince against his will granted their request and allowed for a short time open dealing again, with the exception, however, that all trade with Bohemia was prohibited, because the Bohemian works, on account of the scarcity of their ore, were only able to exist with the help of the Saxon cobalt, which was of better quality. They then competed with Saxony in the color business. Not very long after this another individual named Schindler, purchased a site in order to build blue color works, and in conjunction with the mining office and with the Prince's permission, he stated his willingness to enter into a contract. Finally an agreement was made for six years in 1649, according to which the four owners of the four Saxon color works, namely, Burkhardt, Ohme, the widow of Schnorr and Schindler were associated. The amount of cobalt which they agreed to take yearly was the same as before, namely, 2,400 hundredweigth. The price remained the same as before, with the exception that one higher grade was introduced which was called No. 1 and was paid at the rate of four thaler 6 groschen per cwt. In all other points this agreement was the same as the previous one. Each one of the contractors was to take 600 hundredweight yearly. Both the works and contractors were forbidden most strictly to deal either in ore or oxide with Bohemia, and all the pearl ash, that is potassium carbonate, which was produced in Saxony was to be delivered to the four works in equal portions. This contract was ratified by the Prince in 1649.

Contract of 1649

By this means a fixed and certain contract was brought into existence again. In the place of frequently changing foreign contractors, four subjects of Saxony acted, each of whom was in possession of a color mill, and therefore had an interest in the preservation and continuation of the contract. The only one who had previously been opposed to this was Hans Burkhardt because he was able without any contract to supply his works with

his own cobalt ore. Thanks to the energetic efforts of the Prince and his officials Burkhardt finally yielded. It is true that some concessions were made to him in the new contract. It was therefore of great importance that in the year 1651 the Crown Prince, Johann George, came into possession of the Oberschelma works and Burkhardt's cobalt mines. Burkhardt had died without heirs and relations, and in his will he had left to the Prince his four mines and all his works. The only reason that he gave for this was that the mining and the color business might remain as it was. By this means the Prince had more direct interest in the mining and color industry than he had before. At the same time a request came from some foreign company that they should receive permission for the erection of blue color works. The four contractors, of course, opposed this and requested that for a period of twelve years no new color works should be built in Saxony. They stated that the production would be overdone if further concessions were given, and the individual works would only ruin one another. They stated that there was an example of this in Bohemia, where after the erection of several mills, they had all been ruined except one, and moreover they stated that the pearl ash which was produced in Saxony was not sufficient for the four works which existed. They had to import two thirds of their pearl ash from Bohemia.

The mining office agreed with this request of the contractors for the reasons given above, and advised granting a concession for twelve years on the condition that the contractors after the expiry of this contract should be willing to make a new one. It was certainly, under these circumstances, a good thing for the other proprietors of color works that the Prince himself was interested in one of the four. After some hesitation and urging on the part of the mining office, the Prince agreed that no new rights to build any color works should be given in Saxony. On their part the contractors were bound not only to keep the present contract strictly, but after its expiry to make a new one under more reasonable conditions "in order that the work which had so well begun should come down to posterity and flourish in vigor."

We see that by this means the foundations were laid for an industry which has lasted to the present time, for after the twelve years had lapsed, although there were some attempts to build new works in Saxony the four works that existed at this time were rooted so firmly that every attempt to encroach on their privileges was bound to fail.

CONCLUSION

The Period from 1653 to the Present Time

According to the agreement mentioned above there were four works, each of which was bound to take a certain quantity of ore yearly. One of these works was considered as a double one, and therefore the whole quantity was divided into fifths. The Oberschlema work was the double one. It will be noticed that one of these works belonged to the Prince and the other three were private. The three private works, which had been originally quite independent, in the course of time gradually came out of the control of single individuals into companies, which became more closely related to one another. As far back as 1659 the holders of the different works were agreed on the following points:

1. All the works bind themselves to a fixed price for color below which no color may be sold. The common color cost 5 thalers per cwt. and the best color 10 thalers at the works. At Leipzig it was half a thaler per cwt. higher, and increased with the distance from the works.

2. None of the works during the period of the contract was to make more than 24 cwt. of color weekly.

3. Each of the works had to brand its casks of color with a certain brand in order that they could distinguish their domestic color from the foreign or Bohemian.

Later on, in 1845, the three private works were amalgamated into one and concentrated at Niederpfannenstiel. The works belonging to the State at Oberschlema

remained as it was. Both these combinations are in union and form the so-called blue color trust. This owns all the Schneeberg mines, as well as the mine and works at Modum in Norway. Between the two works the old arrangement with regard to the disposition of the cobalt and the sale of cobalt still exists, viz. two-fifths and three-fifths. In all matters concerning the cobalt business they act in concert and exchange experiences, and experiments are undertaken at the common expense.

Leaving Bruchmueller's work and turning to the annual official reports it appears that the two works employed last year 255 men, including office staff, and that the product amounted to about 674 tons in weight and about $836,000 in value. (Jahrbuch fuer Berg und Huettenwesen).

Present State of Mining in the District of Schneeberg, Saxony

The chief characteristics of the vein systems are given on preceding pages (61, 63).

Taking the only mines which have any production at all worth mentioning, and looking at the reports of the last ten years or so, it is evident that the character of the vein filling has changed since the early days. Bismuth now occupies an important position, as, wherever the contents of ore are given the percentage of bismuth stands high. Quotations from the Annual Reports show this. (See Jahrbuch fuer Berg und Huettenwesen in Koenigreich Sachsen). Silver is quite insignificant in amount, less than two per cent. of the value being credited to this metal. Thus in the report of 1893 (later reports give the value of silver, cobalt, nickel and bismuth together). The amount assigned to silver, etc., reduced to our currency, is as follows:—

Silver	$2,700 00
Cobalt, nickel and bismuth	157,335 00
Uranium	1,666 00
Quartz, specimens and tailings	1,080 00
Total	$162,781 00

In the report of 1905:

Silver, cobalt, nickel and bismuth	$148,581 00
Quartz, specimens, etc.	1,855 00
Total	$150,336 00

The value per ton was about $570.

The result of all the development work being carried on now, consisting of drilling, drifts, cross cuts, rises, and sinking,—in short, trying in every way to open up veins known to be productive formerly or discover new ones,—is that here and there a rather small body of good pay ore will be found. Evidently the early productive period is long past. Occasionally they encounter difficulties due to striking old excavations, with accumulations of water or to the caving in of old work. Most of the work appears to be carried on a depth of less than 1,000 feet.

Below are given translations of extracts from the Annual Reports, extending back about ten years. The reports are all on one mine, or rather, group of mines which was referred to above as being the only one of any importance. It is called Vereinigt Kobaltfeld. About half a dozen veins are mentioned throughout the reports. Some of these were exploited in the early period of mining in that district.

In the report of 1893:

"On the Junge Zeche Spat, (one of the most productive veins in recent times) in a drift of about 280 feet in length for a distance of 83 feet, solid bismuth ore sometimes ten inches wide with 30 to 50 per cent. bismuth was found, also concentrating ore along a distance of 183 feet. The minerals were bismite, native bismuth, smaltite, chloanthite, native silver, ruby silver, argentite, galena in vugs with mimetite (arsenical lead chloride), eulytite (silicate of bismuth), cobalt bloom, chalcopyrite, chalcocite, and cinnabar."

"The most important strike in the whole district was made on a vein which was 16 to 24 inches wide and carried very rich bismuth cobbing ore for 52 feet in length and then concentrating ore for 296 feet."

"A body of ore 45 feet long with a considerable amount of roselite (lime cobalt arsenate) was found."

In report of 1900:

"Exploration of the most improtant vein, Junge Zeche, was undertaken. The productive portion of the vein ended at a depth of about 830 feet from the surface. (This was the case with most of the veins)."

Report of 1901:

"In a crosscut 770 feet from the shaft a strike of rich bismuth ore, sometimes with disseminated ruby silver, also cobalt bismuth ore associated with pitchblende (uranium ore) and niccolite was made."

"A strike was made in the granite[9] over 230 feet from the slate contact, of rather a large bunch of bismite, with native bismuth. Near the contact the bismuth ore was richer and was ten inches wide."

"Another strike was made in a drusy quartz vein over three feet wide where solid cobalt nickel ore was found on the hanging, and bismuth on the footwall."

Report of 1902:

"Junctions of veins proved especially rich in native bismuth. Along with bunches of bismuth ores were associated cobalt-nickel ores and uranium."

Report of 1903:

"From an area of vein surface of about 270 square yards about fifteen tons containing 19 per cent. bismuth, 4.3 per cent. cobalt and 2 per cent. nickel was taken," (the width of the vein not given in this case). "Another ore body containing 20.6 per cent. bismuth and 3.6 per cent. cobalt was found. The contact again proved favourable."

"In a vein 44 inches wide bunches of bismuth ore occurred."

Other strikes mentioned contained 7.3 per cent. bismuth, 5.6 per cent. cobalt; another 33.9 per cent. bismuth, 2.6 per cent. cobalt, and 1.3 per cent. nickel.

1904 report:

"Strike was made 24.2 per cent. bismuth, and 4.1 per cent. cobalt."

"A stringer was found containing pucherite (vanadanate of bismuth) showing throughout all the ore."

Report of 1905:

"Strike of ore was made 25 feet long (width not given) with 21.4 per cent. bismuth and 2 per cent. cobalt. Another strike of bismuth ore of shipping quality 28 feet in length and about 35 feet of concentrating ore. The vein was about 20 inches wide, consisting of quartz, hornstone with bands of bismuth ore and contained 28.6 per cent. bismuth as taken out."

These rare minerals and their associations are mentioned in order that those interested in the Temiskaming district may look up the descriptions of the various minerals and be on the watch for them.

It is remarkable that of all the metal mines, some hundreds in number, which once produced ore in Saxony, and which played such an important part industrially, and also technically, in the development of the art of mining, concentration and smelting, the cobalt-bismuth-silver mines of to-day are the only one which are not operated at a loss.

[9] The granite is younger than the schists in which the veins are found, and underlies them.

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VOL. XIV. - PART III.

THOS. W. GIBSON, Director

THE SUDBURY NICKEL FIELD

BY

A. P. COLEMAN

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MAP
OF
COPPER CLIFF MINE
AND
VICINITY
BY
A.P. Coleman.
14TH REPORT BUREAU OF MINES
PART III
Thos W Gibson, Director
CLARA BELL LAKE
LADY MACDONALD
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Copper Cliff Mine
SOO BRANCH C.P.R.
SNIDER
McKIM
KELLY LAKE
Lot 1
Lot 12
Lot 11

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REPORT OF THE BUREAU OF MINES 1904

VOL XIV Part III

Thos. W. Gibson, Director

THE SUDBURY NICKEL REGION

BY A. P. COLEMAN

Introduction

During the past three summers field work has been carried on by the Bureau of Mines of Ontario, in the Sudbury nickel region, with the object of determining in detail the boundaries of the nickel-bearing rock, and of examining the geological relationships of the known ore bodies, special attention being given to working mines. The field work and the preparation of the previous reports on this region, as well as of this final report, have been entrusted by Mr. T. W. Gibson, Director of the Bureau of Mines of Ontario, to the present writer. It is intended that this report shall sum up as completely as may be our knowledge of the geology of the region, of its ore deposits and minerals, and of the mines which have been operated.

The field work has been done by the writer and various assistants, especially Mr. M. T. Culbert, who deserves particular mention for his quickness of apprehension and skill as a field geologist. The compilation of the accompanying maps also is mainly the work of Mr. Culbert, though much assistance has been obtained from the officers of the Surveys branch of the Department of Crown Lands, who furnished copies of the township maps of the region; and from the work of Drs. Robert Bell and A. E. Barlow, of the Geological Survey of Canada, whose published maps have been of the greatest assistance.

The surface plans of mines have been made partly by myself and my assistants, taking advantage, however, of any existing plans furnished by mine managers or surveyors. The plans of underground workings have been provided mainly through the courtesy of mine owners and managers. In the preparation of these plans for publication Mr. W. E. H. Carter, until lately Secretary of the Bureau of Mines, has been very helpful.

Valuable aid has been given by prospectors, miners and others connected with the nickel mining industry in all parts of the region, but special thanks are due to Mr. A. P. Turner, President of the Canadian Copper Company, and Mr. John Lawson, who has charge of their mines.

The Sudbury nickel field has long been known as the most important source of that metal in America, if not in the world, but the work of the last three years has brought out more and more strikingly the unique character of this mining region. It has been proved that all the ore deposits of any economic importance are at or near the outer

margin of a huge laccolithic sheet of eruptive rock a mile and a quarter thick, 36 miles long and 17 miles wide. This sheet is now in the form of a boat shaped syncline, with its pointed end to the southwest and its square end to the northeast. The rock composing this sheet is norite at the outer (and lower) edge, merging into granite or grano-diorite at the inner (upper) edge. The ore bodies are round the margin of the norite or along dike-like offsets from it, and have evidently segregated from the rock while still molten, though they may have undergone later rearrangement by circulating water.

It is common to find ore deposits associated with eruptive rocks in such a way as to suggest that the eruptive furnished the ore; but in a large majority of the examples described the ores themselves have been transported and deposited by circulating water. In the Sudbury region, however, there is good reason to believe that the ore accumulated at the edges of the eruptive sheet while it was still fluid enough to permit the segregation and sinking of the heavier ingredients, probably, in part at least, under the action of gravitation. At a later time, however, there was in many deposits a considerable amount of water action, particularly in those along offsets. The conditions just mentioned are of very great interest, both from the geological and the economic side, and the evidence regarding them will be given in detail at a later stage.

While special attention was paid to the great eruptive sheet and its ore bodies, the adjoining rocks also have been collected and to some extent carefully studied and mapped; but this work has been subordinated to the main object of the investigation. It has been found that everywhere the laccolithic sheet rests on ancient, mainly crystalline, rocks which have hitherto been mapped and described as Laurentian and Huronian, while its upper surface underlies a series of later rocks which Dr. Bell suggests may be Cambrian in age. This inner rock series consists entirely of sediments, mainly ordinary clastics, such as conglomerate, slate and sandstone, but near the base including much pyroclastic materials, volcanic ash, lapilli, etc. These stratified rocks have been bent into synclines and anticlines during the formation of the main syncline. The underlying more ancient rocks present much less regularity, and their relationships are less certain. The rocks mapped as Huronian are chiefly sediments such as quartzite and graywacké tilted into positions more or less approaching the vertical, and often recrystallized into schists. With them are basic eruptives of great variety, including lava flows and an older, more basic, norite than that of the nickel-bearing rock. The rocks mapped as Laurentian include granite and gneiss younger than the Huronian, but older than the nickel-bearing eruptive and the overlying sediments. The youngest rocks of the region are the laccolithic sheet connected with the nickel ores and certain still later dikes of olivine diabase and granite.

It will be seen that the region presents a wide range of interesting features to the mining engineer as well as to the geologist. and the recent developments in the way of mining operations and the making of wagon roads and railroads enable one to study its southern side in a very satisfactory way; but the northern half is still forest covered for the most part and rather inaccessible.

The mining community and prospectors are accustomed to speak of two nickel ranges, the main or southern one, and the northern one. Our mapping proves that there is really only one range, which is continuous with the outer edge of the sheet of nickel-bearing rock. However in a modified sense the two ranges may still be distinguished, since the extreme west and the extreme east of the laccolithic sheet have not yet disclosed ore bodies of importance. In a general way there are more numerous and larger ore bodies, so far as known, on the southern than on the northern range, though there is great irregularity in this respect on both ranges.

As will be shown later the topography of the region has very close relations with the arrangement of the laccolithic sheet and its adjoining rocks, so that the surface forms of the area give aid in studying its geology.

PREVIOUS GEOLOGICAL WORK IN THE REGION

Nickel ore was first found in what is now the Sudbury district in 1856 by Murray who obtained it near the present Creighton mine, where Salter, an early land surveyor, had noted great disturbance of the compass. Dr. Sterry Hunt analysed the material, finding in it nickel and copper.[1] No further discoveries of nickel ores were made until the Canadian Pacific railway was constructed in 1883, when the ore body of the Murray mine was disclosed; and in the following year the Stobie, Copper Cliff and other deposits. The mineral which attracted attention was however the copper pyrites and not the pyrrhotite, and the deposits were valued only for their copper contents, as the name of the famous "Copper Cliff" mine suggests. It was not till three or four years later, when some thousands of tons of ore had been shipped for treatment from the latter mine that the value of the nickel ore was recognized.[2]

In the Geological Survey report for 1890 Dr. Bell's report on the Sudbury mining region appears as part F, including the results of his field work from 1888 and 1890, as well as those of Barlow and various other assistants; and in the same year the Report of the Royal Commission on the Mineral Resources of Ontario contained a number of references to the region by Dr. Bell and others.[3] In the following year Dr. Bell contributed an account of the ore bodies of the region to the Report of the Bureau of Mines,[4] and the same volume contained the first statistics of the production of nickel ore. Since then the nickel contents of the matte have been reported year by year, and various references are made to the mines and their geological relationships by mining inspectors and geologists, as well as accounts of the metallurgy of nickel and its value in the manufacture of armor plate, etc. It was in 1891 also that Garnier, the discoverer of the New Caledonian nickel ores, published an important account of the Sudbury nickel mines;[5] while in the following year another French mining engineer, M. Levat, described the treament of the Sudbury ores, comparing them with those of New Caledonia.[6]

In the same year the real character of the nickel-bearing rock was discovered by Baron von Foullon, who found hypersthene and diallage in specimens from the Murray mine, proving that it belonged to the norite variety of gabbro instead of being diorite, as former students of the region had named it.[7]

In 1893 the present writer showed that the country rock of certain nickel deposits on the northern range contained diallage and enstatite, and so should be classed with the gabbro family;[8] and somewhat later Dr. T. L. Walker, in an Inaugural Dissertation on the Sudbury Nickel District, proved that where unweathered the nickel-bearing rock contains hypersthene and hence is norite, as von Foullon had stated. He made another still more important observation, that this basic rock passes by insensible gradations into syenite and granite.[9] The present writer had found micropegmatite associated with the nickel-bearing rock but had not observed that the one passed into the other.[10] To Dr. Walker belongs also the credit of first recognizing the field relationships, showing that the transition from norite to pegmatite was from southeast to northwest near the Murray mine; but in the reverse order near Onaping, so that the basic edge was on opposite sides of the two nickel ranges.

That the ore is really a very basic segregation from the margin of the eruptive mass with which it is associated was brought out in 1894 by Dr. Adams, who followed the theory proposed by Vogt for the Scandinavian nickel deposits.[11]

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1 Geol. Sur. Can., 1853-6, pp. 180 and 189.
2 See Dr. Bell in Bur. Mines, 1891, p. 89
3 Pp. 23, 67-8, 88, 100, 404-5 and 433-5.
4 Pp. 88-90.
5 Mem. Soc. des. Ing. Civils, 1891.
6 An. des Mines, 1892, Tome I, 2 Livraison; see also translation in Bur. Mines, 1892, pp. 149, etc.
7 Jahr-b. d. k. k. geol. Reichsanstalt, Vienna, 1892, pp. 223-310.
8 Rocks of Clear lake near Sudbury, Can. Rec. Sc., Apr. 1893, p. 344.
9 Quar. Jour. Geol. Soc., Vol. LIII, pp. 40-46.
10 Can. Rec. Sc., 1893, p. 345.
11 Can. Min. Rev., Jan. 1894, p. 8.

In 1901 Dr. Barlow gave a brief account of the rocks of a portion of the southern nickel range, in which he described excellently the norite and its gradation into micro-pegmatite.[12] Later his large scale maps of the Copper Cliff and Victoria mines regions have appeared, and a further summary report on rocks of the region in 1902.[13] In the latter year the first detailed report of the Bureau of Mines was prepared, taking up especially the working mines of the southern range, of which maps and plans were published; and in 1903 the work of mapping the northern nickel range was nearly completed.[14].

In 1904 Dr. Barlow's admirable final report on the region was published as Part H of the Geological Survey report for that year. It is much the most complete account of the region yet given, and should be referred to by anyone desiring a full knowledge of the geology, and also of the economic development of the Sudbury district. Several useful maps of parts of the district are published with the report.

In the foregoing review of the literature of the subject only reports and papers of a geological nature have been referred to. Many papers have been published on the mineralogy, metallurgy, and mining of the district; but these will be noted in later portions of this report.

It will be seen that the region has attracted much attention and has been studied in whole or in part by many geologists. It was, however, a very difficult region for geological work in earlier days, being rugged and forest covered, and in most parts unprovided with the canoe routes which facilitate geological work in so many parts of northern Ontario. The real field relationships could only be determined by following up in detail the basic edge of the eruptive, thus proving that it is continuous and not merely a series of larger or smaller bands of basic eruptive rock.

The map constructed by Dr. Bell and his assistants was in some respects surprisingly accurate and served an excellent purpose in its time, though later work under more favorable conditions has thrown new light on many points and has given the clue to the general relationships.

TOPOGRAPHY

The topography of the Sudbury district is very closely bound up with its geology, the great laccolithic sheet especially influencing the land forms. The ancient Huronian and Laurentian rocks outside the eruptive sheet have a varied, but generally rugged and hilly, surface, the harder quartzites and granites rising as steep hills or ridges, while the softer rocks make the low ground, largely covered with old lake deposits or by lakes and swamps.

The nickel-bearing eruptive varies considerably in different parts, and these variations express themselves in very different types of topography. The basic phase of the rock yields readily to weathering, while the acid phase is a very resistant rock. The basic edge has had little effect on the rocks with which it is in contact, the so-called Huronian and Laurentian, so that the topography outside the basic edge depends on original differences in the character of the Archean rocks themselves. On the other hand the acid edge has powerfully metamorphosed the overlying sediments, turning them into very crystalline and durable rocks. Half a mile inward from the acid edge the tuffs and slates are much softer; but in the centre of the syncline there are thick sandstones of a more resistant nature than the slate.

The relationships just sketched furnish an explanation of most of the topographic features, which may now be discussed briefly. The exposed surface of the eruptive along the southern edge of the syncline is often four miles wide and averages more than three miles in width, of which the outer half is basic and weathers rapidly. Along the

12 Geol. Sur. Can., Sum. Rep., p. 143, etc.
13 Ibid. 1902, pp. 252-267.
14 Bur. Mines, 1903, pp. 235-299; and 1904, pp. 192-224.

northern side the width varies from three miles to less than one mile, averaging nearly two miles, of which less than one-half is basic as a rule, and in places the basic portion is almost lacking.

The topography in general is then as follows: the country outside the syncline has the somewhat rugged and irregular mixture of hills and valleys of rather moderate heights and depths usual in Archean regions. The basic edge of the southern nickel range follows, with low, gently accentuated surfaces for a width of about two miles; after which comes a belt of quite precipitous hills belonging to the acid edge. The adjoining metamorphosed conglomerate and tuff makes a narrow band of very precipitous hills, often having unscalable cliffs. The inner, softer tuffs and slate make the floor of a wide valley, followed by hills of sandstone in the middle of the syncline, much lower however than the other hills referred to before.

Approaching the northern nickel range, after a flat valley representing the slates and softer tuffs, one finds once more a very mountainous band of country formed by the metamorphosed tuffs and the acid eruptives; then a narrow valley, often filled with a lake or muskeg, at the basic edge; followed by the irregular Laurentian hills to the north.

The contoured portion of the map accompanying this monograph illustrates graphically the relationships just referred to, so that detailed description is unnecessary. It should be remarked however that this section was chosen because of the convenience of the railway bench marks in working out the levels, and the railway has naturally selected the easiest passes into and out of the flat central valley. The acid edge near Azilda presents a much less rugged appearance than is usual in other parts of the range.

Although the country along the acid edge is so precipitous and rough in character as to cause difficulty in running lines because of vertical or even overhanging cliffs, the total difference in altitude from the flat interior of the basin to the enclosing hill tops is not more than about 600 feet, so that the elevations can scarcely be called mountains. The highest points measured reach not much over 1,400 feet above sea level.

In general then there is an elongated central area of low ground with comparatively gentle hills running down its centre, surrounded by a margin of very precipitous hills rising from 200 to 600 feet above the plain. Then comes a valley about a quarter or half a mile wide on the northern side and two miles wide on the southern, succeeded by the irregular hilly country of the outside Archean. The interior plain as well as all the low ground to the south of the eruptive area is covered with lacustrine clay or sand, while the less frequent level ground to the north consists of sand nad gravel terraces at higher levels.

HYDROGRAPHY

In a region so recently ice-covered as northern Ontario the arrangement of the lakes and watercourses is of a very youthful character, very little filling of basins, or cutting down of rocky obstructions having taken place, and yet the old topography profoundly affects the drainage system. The main river of the district, Vermilion river, comes in from Archean country to the north as a singularly straight north and south chain of narrow lakes connected by swift water or rapids. As soon as the hilly border is passed by an evidently pre-glacial channel the river changes its character, flowing gently over drift sand and gravel at the northwest end of the interior basin to lake Onwatin, an expansion in the soft slates. It then turns west for twelve miles, and afterwards southwest for six miles, keeping to the band of slate almost to Larchwood, where it cuts across the low sandstone ridges, forming rapids and falls. Arrived at the southern band of slate it expands into Vermilion lake, a counterpart of Onwatin, as noted by Dr. Bell, turns east for five or six miles of placid water, and

finally strikes southwest across the acid edge as lake-like stretches separated by rapids or falls. It receives one large tributary, the Onaping, which plunges as a succession of violent rapids and falls where it crosses the acid edge on its way from the north into the central plain towards its eastern end. It then turns east following the slate until it joins the Vermilion above Larchwood.

Fall on the Onaping over vitrophyre tuffs.

The smaller tributaries largely occupy the same band of slate, and it is clear that the whole drainage system is mainly controlled by the peculiar geological structure of the region.

With the exception of Onwatin and Vermilion lakes, which have in general flat low shores and are merely expansions of Vermilion river, the low central area of sedimentary rocks contains no important lakes, except Whitewater, which has its northern shore within the tuffs. All round the hilly edge of eruptive rock, however, we find typical "rocky lake" country with irregular steep shored bodies of water, such as Fairbank, Windy, Trout and Whitson lakes. Along the northern basic edge of the eruptive there are many small narrow lakes whose basins are due to the rapid decay of the norite between walls of granite and gneiss to the northwest and the acid phase of the eruptive toward the southeast. The wider valley of the southern basic edge has lower hills and more numerous openings toward the southeast, and its hollows are mainly filled with drift, so that there are few lakes along that side.

The lakes of the interior basin are shallow and have muddy shores, while those of the hilly border are often very deep with rocky shores and clear water. They stand usually a hundred or more feet above the valley, and the small streams which drain them are full of rapids and falls.

The Vermilion river and its tributaries in the interior valley have very meandering channels, and are engaged in carving down the old lake deposits to the base level of the

next lower outcrop of rock. In the rocky country on each side of the basin their channels are determined by the irregularities of the rocky valleys, where practically no cutting has been done since the glacial period except in the unevenly distributed boulder clay.

METHODS OF SURVEY

Different parts of the Sudbury district are in very different stages of development, the southern portion being well supplied with wagon roads and railways, and having a number of towns and villages, as well as cultivated farms in the clay covered flats and valleys. Most of the country near the great mines has been cleared and burnt over, sometimes more than once, so that the rock is excellently exposed, except where buried under old lake deposits. The northern range, on the other hand, is still largely a wilderness covered with woods and with few roads except those of the lumbermen, who are now removing the pine.

These differences are partly due to the richness of the mines in the southern range, but perhaps in an equal degree to the passage of the main transcontinental line of the Canadian Pacific railway through it. The latter circumstance has its cause in the gentler character of the country in the southern part, resulting probably to a considerable extent from the much greater width of the norite margin of the eruptive. Norite weathers quickly and where wide forms a comparatively level surface with gentle hills.

The town of Sudbury is southeast of the main nickel range, and from it radiate railways in various directions, the main line of the C. P. R. running roughly east and west through the district; the "Sault" branch turning off to the southwest; the Algoma Central running for eleven miles about midway between it and the main line, following the basic edge of the eruptive where various mines are at work; and finally a branch running north three or four miles to the Stobie and other mines not now working.

The whole district has been surveyed into townships six miles square, and the lines between the square miles have been run, as well as occasionally north and south lines dividing the square miles into halves. Unfortunately for the geologist many of these surveys are now old, and the lines have grown up or have been obscured by lumbering operations, or fire has actually destroyed all evidence of the surveyor's work, so that following the lines is difficult and often impossible. On this account much topographical work has been required to fix the geological relationships, especially the contacts of the inner or acid edge of the nickel-bearing eruptive with the overlying sediments. It was decided to determine the position of the acid edge at points not more than a half mile apart, the usual method being by pacing from corner posts to the point of contact, while the basic edge was mapped in a more detailed way, especially in the neighborhood of mines or ore bodies. The latter work was done partly by pacing and prismatic compass, or where there was local attraction, by dial compass; and partly by micrometer work. There are parts, however, especially toward the southeast corner of the boat shaped syncline and at its southwestern end, where swamps or drift deposits hide the solid rock and leave some uncertainty as to the line of contact. The longest stretch covered in this way is in the townships of Falconbridge and Maclennan, where there is a gap of a little over two miles.

During the field work in the southern part of the region railways were largely made use of as bases, and in several places there are good wagon roads which were of service in tracing the basic edge. For the basic edge on the northern range and for the acid edge everywhere, these modes of access were seldom available and the work was done by tramping through the woods, or, where possible, by canoes on lakes and rivers.

It was found that the township maps as well as the maps of mining locations are usually accurate in so far as lines which had actually been surveyed are concerned, but that the courses of rivers and the forms of lakes are commonly very badly mapped, and that many smaller lakes not cut by a survey line have been omitted altogether.

The levels of the region have been determined mainly by aneroid from fixed points such as railway stations and bench marks, White's Elevations of Canada being made use of. In order to give an idea of the topography of the country for a mile or two on each side of the Canadian Pacific railway from Murray mine to Windy lake has been contoured, the lines being placed 25 feet apart. The work was done partly by hand level and partly by aneroid, and except near the railway great accuracy of detail was not aimed at. Owing to lack of time and the smallness of the staff available it was not possible to contour the whole district, but elevations of many of the higher points and of the chief lakes are given on the map. As these were determined by aneroid, and often at long distances from the railway, their accuracy is only approximate.

CLASSIFICATION OF THE ROCKS

Underlying the sheet of nickel-bearing eruptive there are various sedimentary and eruptive rocks which have always been placed in the Laurentian and Huronian. The Laurentian was originally supposed to be the older of the two, but it is now known that it has, in many places if not all, an eruptive contact with the Huronian, so that its age must be later. The Laurentian consists wholly of eruptive rocks but the Huronian contains more sediments than eruptives. The oldest rocks of the district are the banded iron formation and the schists associated with it, but they nowhere occur in the neighborhood of the nickel ranges, though they are developed in interesting ways on the north shore of lake Wahnapitae not far to the east, and in Hutton and adjoining townships to the north. The iron formation consists of silica of a quartzitic or jaspery kind interbanded with magnetite, in Hutton township affording great bodies of fairly good magnetic ore.[15] These rocks have been placed in the Lower Huronian by the geologists of the Bureau of Mines, the equivalent of the Keewatin as lately defined.

Their relationship to the sediments south of the southern nickel range is not quite certain, but the latter are generally considered younger and have hitherto been put with the rocks of the original Huronian area as Upper Huronian, but by the new classification will be Lower Huronian.

The widespread sedimentary rocks south of the nickel range differ materially from those of the original Huronian, however, containing no bands of limestone nor red jasper conglomerate and very little white quartzite, and being generally more extensively metamorphosed. They include distinctly stratified graywacké or quartzite with slaty bands, probably with a synclinal arrangement, as suggested by Dr. Barlow, since there are two parallel bands with arkose between. The arkose, though apparently later than the graywacké and included in its syncline, shows very little evidence of stratification in most places, and is often so far re-crystallized as to look like felsite or fine-grained gneiss. It has frequently been taken for an eruptive, and has been spoken of as syenite, but its parallelism with the well stratified graywacké and its general field relations make it almost certainly a sedimentary rock. The slaty graywacké is often crowded with whitish or gray pseudomorphs after staurolite, and is what Dr. Selwyn named "rice rock." Occasionally the pseudomorphs are far too large for grains of rice, and reach four or five inches in length.

When the slaty graywacké lies beside large granite masses, as near the Frood mine, it may become more schistose, so as to form mica schist or fine-grained gneiss.

In some parts of the region, especially toward Whitefish and Worthington, there are pale gray and very cleavable slaty rocks without the coarser textured layers, probably of the same age as the rocks previously described.

North of Ramsey lake and in other places there are considerable areas of graywacké conglomerate, usually showing little evidence of stratification and consisting of a dark gray or black matrix enclosing angular or rounded pebbles and boulders of

[15] See Bur. Mines, 1903, pp. 318-321; and 1904, pp. 216-221 and 222-224.

various rocks, such as vein quartz, quartzite and granite. In appearance they suggest a greatly metamorphosed boulder clay, and it is not impossible that they originated by ice action.

Though the relations of this conglomerate to the slaty graywacké are somewhat obscure, it appears to be younger, the quartzite boulders probably coming from harder quartzitic layers of the previously mentioned rocks.

A narrow, discontinuous band of undoubtedly water formed conglomerate, very like some parts of the typical Huronian conglomerate north of lake Huron, stretches for about two miles northeast and southwest near Stobie mine; and near by is a small hill of white quartzite like that near Lake Huron. Just how these rocks should be placed with regard to the more widely spread rocks is uncertain, but they have been tilted and faulted in the same way and are probably of the same general age, *i.e.*, Huronian.

All the older rocks of the region have been greatly faulted, the faults being very numerous but usually with a small throw; and in various places there are crush conglomerates along the planes of faulting. Dr. Barlow in his map of the Copper Cliff region indicates a series of close folds in the schistose rocks, and it is quite probable that most of the Huronian has been sharply folded by the elevation of neighboring Laurentian areas, but our work was not detailed enough to prove this relationship.

Eruptive Rocks in the Huronian

The sedimentary rocks described above are associated with green schists and various greenstones and other basic eruptives which seem to be of much the same age. The schists may be sheared diabases or gabbros, now reduced to chloritic and hornblendic rocks; but beside them or intermingled with them are hornblende porphyrite, with large crystals of hornblende, and white spotted rocks, perhaps once porphyrites containing feldspar crystals. In many places these rocks pass into a very fine-grained norite, entirely different in character from the nickel-bearing norite, and of course much older than that important rock. In a few places there are well developed "pillow structures" and amygdaloidal or concretionary forms that must be explained as resulting from surface volcanic flows. Hills made up of these various basic rocks extend for several miles along the southeastern edge of the main nickel range, from Blezard to Elsie, and they are found less extensively in several other parts of the region.

Other basic eruptives, such as hornblende porphyrite and gabbro, form long bands or sometimes small laccoliths entirely enclosed in the Huronian sediments and often tilting them up in such a way as to prove them later in age, as in the hill east of Sudbury and a ridge south of Copper Cliff. Though later than the sediments they are supposed to be older than the nickel eruptive, and may represent earlier effusions of the same magma, since small pockets of nickel ore occur in them.

Fine and coarse-grained granite also penetrates the arkose, in general older than the nickel-bearing rock, though one band of red granite near Murray mine seems to have been later. Some of the granite may even be a re-melted or re-arranged part of the arkose, though this has not been clearly proved.

At one point north of Sudbury a grayish quartz-porphyrite rises through the arkose, superficially very like the enclosing rock.

In general all these acid eruptives and many of the basic ones, though later in age than the Huronian sediments, are older than the nickel-bearing eruptive and the rocks which overlie it; and are considered to belong to the Huronian rather than to any later series.

The Laurentian

In addition to the medium and fine-grained granites mentioned above there are coarse granites and syenites often porphyritic, which merge into gneiss and have been

placed in the Laurentian by most writers. There are considerable areas of these rocks from Copper Cliff west to Creighton mine, evidently younger than the green Huronian schists, since they contain patches and elongated strips of them; but generally older than the norite, which often grows finer-grained where it approaches them. Still farther to the west is a great area which has always been mapped as Laurentian, and this expands to the northward and forms the northwestern country rock of many of the ore bodies along the northern nickel range.

There is a good deal of variety in these rocks, most of which are granitoid gneisses of a dull flesh color. They may have the composition of syenite or of grano-diorite, and very commonly they include angular or tailed out masses of greenstone or green schist, sometimes of large extent. The gneissoid structure is sometimes parallel to the edge of the norite, but at different points it may be found striking in almost any direction, so that the schistosity is probably older in origin than the nickel-bearing rock, and not a result of that eruption, like the schistosity of the Huronian rocks just to the southeast of the main nickel range. There are probably granites of later age enclosed in the granitoid gneiss, but, so far as known, these are older than the nickel eruptive. A bright flesh red granite of coarse texture, cut by the Foy offset from the northern nickel range, is probably of this character.

Comparatively little time has been devoted to the Laurentian, and it should be stated that more or less greenstone or green schist, probably of Huronian age, and even a few small bands of the iron formation are covered by the Laurentian color. Comparatively large greenstone areas are known to exist west of Windy lake and east of Blue lake, near lake Wahnapitae, but lack of time prevented careful mapping of these tracts, and they are not separated from the Laurentian.

In our classification all the rocks referred to the Laurentian and Huronian are considered to belong to the Archean, while the rocks above them are looked on as probably of Animikie or later age.

Rocks above the Archean

The rocks next in age to the Laurentian appear to be the sedimentary series enclosed in the basin of the nickel-bearing eruptive, which probably represent approximately the Animikie of western Ontario. It is curious that these are nowhere found in contact with the two lower series, the Huronian and Laurentian, the eruptive sheet always separating the upper rocks from the lower, evidently because the division between the unmetamorphosed Animikie and the more crystalline Archean provided an easily invaded plane for the laccolithic magma to spread out in. When that took place the upper sedimentary deposits were in a sense floated off from their foundations.

The rocks here classed as Animikie may be subdivided into four formations, the Trout lake conglomerate, the Onaping tuff, the Onwatin slate and the Chelmsford sandstone, employing local names for the sake of convenience of description.

The Trout lake conglomerate with coarse pebbles or boulders of granite and other rocks is evidently basal and now rests everywhere upon the "acid edge" of the nickel bearing eruptive, which has profoundly acted on it by heated solutions, so that it is now the most resistant rock of the series.

The Onaping tuff is well displayed at the high falls of Onaping river, where the dark fine-grained volcanic sediments overlie the Trout lake formation; but the tuffs occur without a break all round the basin.

The Onwatin slate is black, carbonaceous, and very fissile, and lies between the tuff and sandstone, but is too soft to be well represented in the rock exposures.

The Chelmsford sandstone runs as low sharp ridges down the centre of the basin, being best represented at Chelmsford and Larchwood.

STRATIGRAPHY OF THE NICKEL BASIN

The great complication of the Huronian sediments and the eruptives penetrating them, as well as the interruption of Laurentian granitoid gneiss have made it impossible in the time at our disposal to work out with any definiteness the thickness and detailed relationships of the rocks lying below the nickel eruptive, though their probable succession in age has been pretty certainly determined. With regard to the eruptive sheet itself and the overlying sediments, much more is known and a fairly complete account of their relationships can be given. Though the eruptive is later in age than the sediments, it is convenient to begin with it as the lowest rock in the series.

The Sudbury Nickel-bearing Eruptive

The rock always found associated with the nickel deposits is found to be norite wherever fresh, as shown by von Foullon and Prof. Walker and confirmed by Dr. Barlow and myself; but it is very often weathered so as to have the composition of diorite. It has various shades of gray, generally dark along the most productive part of the southern nickel range, and passes insensibly into pale gray or flesh colored micropegmatitic syenite or granite towards the inner and upper edge. The width of the band is quite variable, running from four and one-fifth miles near the Creighton and Murray mines to five-sixths of a mile at the narrowest part near the northeastern corner of Morgan township. The average width of the southern side of the eruptive band is 3.1 miles, and of the northern 1.9 miles; and the total average width is 2.5 miles. Where the band is wide quite half of it is dark gray norite; but where it is narrower the acid (granitic) portion takes up more than half; and at the narrowest point the noritic phase is almost absent. What has been said of the basic portion of the rock applies in a general way to what may be called its most basic fringe, the nickel and copper sulphides. Roughly speaking, ore bodies are more numerous and larger where the whole eruptive is wide, and less numerous or absent where it is narrow.

The length of the boat-shaped eruptive sheet is 36.2 miles, and its greatest width 16.6 miles, the average width being 13.6 miles; so that the whole area, covered as well as exposed, is 495 square miles. The inward dip of the contact between the ore bodies, or the basic edge of the eruptive when ore is absent, with the underlying Huronian or Laurentian rock runs from 20° to 64°, and the average dip may be estimated between 30° and 45°. As the inward dip of the overlying sediments averages about 30°, this will be taken as the true average dip of the whole series of rocks.

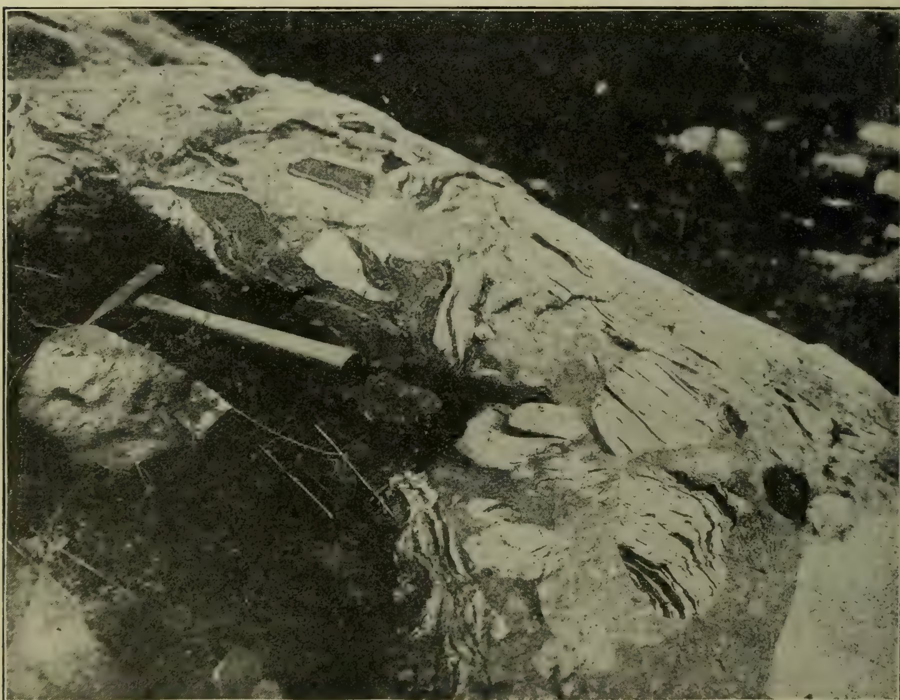
Accepting the dip at 38°, the eruptive sheet has an average thickness of 1.25 miles. If this thickness is retained in the parts hidden beneath the sediments, the total volume of the sheet is nearly 600 cubic miles; but probably the sheet is thicker in central parts, and certainly all the edges have lost greatly by erosion, so that the original volume must have been very much greater than 600 cubic miles. As the circumference of the basin is 80 miles, one mile added to its margin would increase the volume by 100 cubic miles, and in the beginning the total volume may have been 1,000 cubic miles or more. As the basin now stands the northwestern edge of the eruptive has an elevation of about 300 feet above the southeastern edge, perhaps due to more rapid weathering of the much wider basic part found along the southeastern side.

The basic edge sends offsets into the surrounding rocks for distances up to eight miles, in places continuous and dike-like, but often discontinuous and irregular; and the acid edge also projects into the overlying rocks, though none of the apophyses have been traced for notable distances.

The lower rocks have been greatly crushed and faulted, and coarse breccias have often been formed of the blocks, cemented with narrow bands of norite or with ore.

General Features of the Basin

The origin of the synclinal basin whose rocks, ranging from the nickel-bearing eruptive beneath, to the Chelmsford sandstone on top, have just been described is most easily explained by supposing that the source of the 600 or 1,000 cubic miles of eruptive magma now solidified as the great laccolithic sheet was immediately beneath the basin itself. As the magma welled up and spread out broadly beneath the originally horizontal sediments the floor of crystalline Archean rocks (Huronian and Laurentian) collapsed owing to lack of support and underwent great faulting and shearing, as may be seen in the complex system of fault planes and crush breccias displayed near Sudbury.

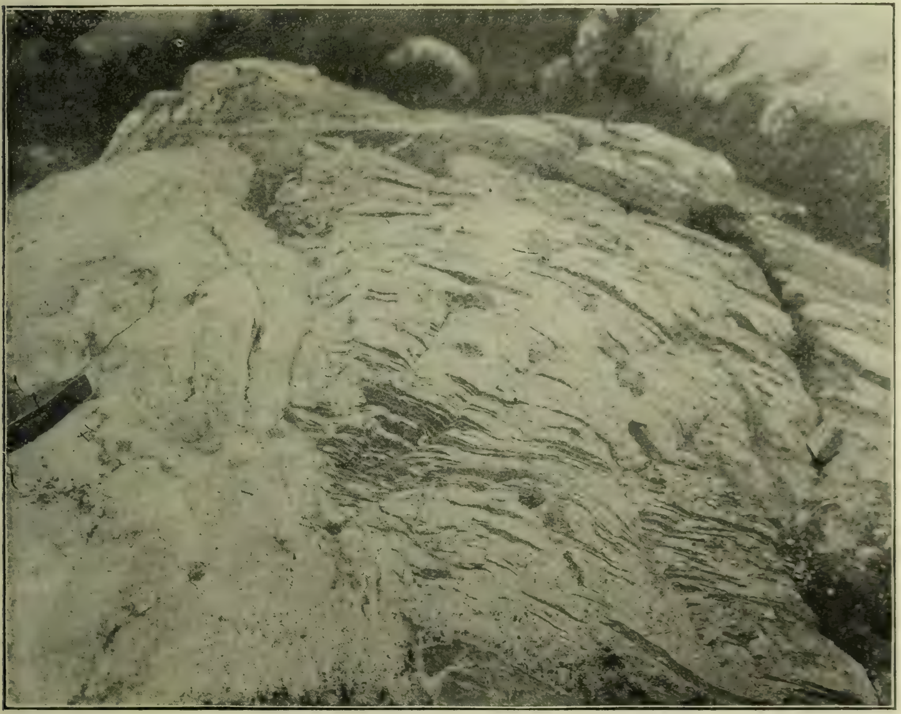


Crushbreccia, hill south of Creighton.

In a general way the sedimentary series of the basin was cushioned by the molten sheet more than a mile thick beneath it, so that faulting is not very prevalent in the upper rocks; but the gradual sinking of the substructure brought the uppermost layer that of the Chelmsford sandstone, into compression, causing gentle anticlinal folds or elongated domes.

The sources of the magma extended from northeast to southwest, so that the main effect of the collapse of the underlying Archean rocks was to produce compression at right angles to this plane. Hence we find a well marked slaty cleavage in all parts of the sediments which were not impregnated with materials from the eruptive and so hardened. The fissure from which the molten rock came was probably somewhat curved, being convex toward the northwest, so that the slaty cleavage in the southwest end of the syncline runs from 50° to 70°, while toward the east end it bends to 80° or even to southeast at the extreme corner.

In general the slaty cleavage is nearly vertical with a tendency to incline toward the southeast; but along that side this tendency becomes more marked until at the edge a well defined schistose structure is developed, dipping even 45° or 35° to the southeast and flattening the pebbles of the basal conglomerate, as on Whitewater lake. Since the eruptive sheet is nearly twice as thick on the southeast as on the northwest side (the width on the surface being 3.1 miles to 1.9 miles) the greater weight may have had an important effect in producing a more extensive collapse on this side, or else the sinking of the substructures was greater here, permitting a thickening of the sheet. The fractured and faulted and slickensided character of the country rock at



Fault hill, south of Creighton

the Creighton and North Star mines may be accounted for in this way. It is possible too that the peculiar broad bay-like margin of the acid edge between Gordon and Whitewater lakes and the projection of two long and important offsets from the basic edge, at Victoria mine and Copper Cliff, as well as the separate nickel-bearing band of Frood and Stobie mines, may be brought into connection with the great weight of the fluid or plastic magma at this part of the southern edge, where it is thicker than elsewhere.

After the eruption of the nickel-magma a long continued process of segregation took place, to some extent at least under the influence of gravitation, the sulphides sinking into depressions of the Archean substratum, and the more acid and lighter portions of the rock rising to the upper part of the sheet. The great thickness of the overlying sediments, estimated at 10,230 feet (with an average dip of 30°) was sufficient to render the cooling exceeding slow, permitting of a very perfect separation of the heaviest ingredients, which were also the most fluid, at the bottom.

Later Eruptives

As explained before, the nickel-bearing eruptive is younger than the series of sediments which rest upon it, but it is by no means the latest eruptive of the district. Penetrating its edge near Murray mine and Copper Cliff there are flesh-colored to gray medium-grained granites, and within the eruptive north of Murray mine and near Whitson lake, as well as in other places, there are pale or flesh-colored granitic rocks, probably later dikes or irregular bosses; so that the main laccolithic sheet was followed by more acid flows of a somewhat later age, but perhaps before the sheet had completely lost its heat.

Probably at a much later time, after the whole region had cooled down, fissures several miles in length and often more than 100 yards wide were opened through all the earlier rocks and filled with olivine diabase, the freshest rock in the region. This took place after even the most fluid and lowest portion of the nickel-eruptive, the pyrrhotite of the ore bodies, had completely cooled, for the dikes cross indifferently from it to the granitoid gneiss or the norite, but have a more glassy edge against the ore than against the other rocks, since the sulphides were better conductors of heat and chilled the dike more quickly.

These very numerous olivine diabase dikes remind one of the dikes and "Logan sills" of the Port Arthur Animikie and may be of the same age, Keweenawan, though there is no direct proof of this, since distinctively Keweenawan beds have not been found in the Sudbury district, the nearest point at which they are known being on the east shore of lake Superior 150 miles away.

Still later than the diabase dikes, and the latest known rocks of the district, except the Pleistocene, are some narrow granite dikes which cut the diabase itself about three miles west of Sudbury. These are probably post-Keweenawan. It is understood of course that all the rocks described are to a greater or less extent covered with boulder clay, moraines, kames and eskers, and that wide-spread beds of stratified clay, sand and gravel deposited in post-glacial lakes come later still; but none of the fossiliferous beds of the Palaeozoic touch the district so as to fix the upper time limit of the unfossiliferous rocks above described. The nearest Palaeozoic strata are the Cambro-Silurian beds of Georgian bay, 36 miles to the southwest.

The succession of rocks in time is given in the following table:

Table of Formations

PLEISTOCENE		Sand and clay.
KEWEENAWAN		Latest granite dikes. Olivine diabase dikes. Granite. Sudbury nickel-bearing eruptive.
ANIMIKIE		Chelmsford sandstone. Onwatin slate. Onaping tuff. Trout Lake conglomerate.
ARCHEAN	Laurentian	Granitoid gneiss.
	Huronian	Acid and basic Huronian eruptives. Ramsay Lake graywacké-conglomerate. Copper cliff arkose. McKim graywacké.

CHARACTER OF THE SUDBURY ORES

The ores of the Sudbury mining district are extraordinarily uniform, three sulphides only making up practically the whole of most of the ore bodies, and only two as a rule presenting themselves to the eye, pyrrhotite or magnetic pyrites, and chalcopyrite or copper pyrites. The third one, pentlandite, is much the most important, though commonly invisible in the ore except at a few of the richer mines, where it appears only occasionally.

The mineral present in much the largest amount is pyrrhotite, a sulphide of iron whose composition as given varies from Fe_5S_6 to $Fe_{16}S_{17}$. It is pale bronze with bright metallic lustre on fresh surfaces, but quickly tarnishes to brown, and very readily weathers, turning to a rusty mass, the gossan which is so characteristic of all the nickel mines. It almost never appears in crystals, though a certain platy character at a few mines suggests crystalline structure, and it may be from coarse to fine-grained. Its property of magnetism distinguishes it from other sulphides, since it is easily attracted by the magnet, while others are not, but the strength of its magnetism varies considerably in different localities, for reasons not certainly understood. The most highly magnetic ore of the region is found at Blue lake toward the northeastern end of the ranges, specimens from there having distinct polarity and attracting iron filings. In other parts the pyrrhotite is too feebly magnetic to do this, though it always shows a powerful effect on the compass or dip needle. Attempts have been made to locate ore bodies where hidden by drift or obscured in other ways by means of the dip needle or more delicate appliances, such as the Thompson-Thalén magnetometer, and a considerable amount of magnetic survey work has been done by Messrs. Nystrom, Kay, Miller and others, for the Mond Company, the Lake Superior Power Company and Mr. Thomas A. Edison. It cannot be said however that up to the present any very important practical results have been attained by this method of exploration.

In a few places pyrrhotite has occurred almost to the exclusion of copper pyrites, as at Gertrude mine, where there was so little copper in the ore that plans were made at the Sault Ste. Marie for roasting it, and reducing the resulting oxide directly to ferro-nickel; but even at the Gertrude, mining operations soon showed a considerable amount of chalcopyrite, making the ore unsuitable for that purpose.

Though the chalcopyrite is generally present in much less quantity than the pyrrhotite, occasionally, as at the Copper Cliff in early days, it may form the larger proportion of the ore. The two sulphides commonly occur together, the brassy lustre of the chalcopyrite distinguishing it from the bronze of the pyrrhotite, and polished surfaces of ore show quite irregular arrangements of the two minerals. They do not appear to be very minutely intermixed as a rule however, and it is not difficult to select fairly pure examples of each.

Pure pyrrhotite contains on the average about 3.21 per cent. of nickel in the Sudbury region, and pure copper pyrites, having the composition $CuFeS_2$, contains 34.5 per cent. of copper. Since the ores of the district produce on the whole about equal amounts of the two metals, the proportions of the two minerals in the ore must be about 10 parts of pyrrhotite to one of chalcopyrite.

The variations in the proportions of the two minerals even in the same ore body are sometimes wide, as at Copper Cliff, where the percentages obtained in different years present differences such as 4.65 copper to 4.46 nickel at one time and 7.81 copper to 2.37 nickel at another. The different mines vary even more widely from one another in this respect, the Creighton, for example, having nearly 5 per cent. of nickel to 2 of copper, in contrast to the percentage given above for Copper Cliff.

It is probable that the chalcopyrite is a little more mobile in the ore bodies than the pyrrhotite, since it is more commonly found filling fissures in the country rock, or as a film between slickensided surfaces of the later diabase dikes. It has been observed also that at Copper Cliff the ore body was richer in copper when narrow, and in nickel when wide, so that the relations to the adjoining rocks appear to have some influence on the distribution of the two minerals.

The third and most important mineral is pentlandite, a rich ore of nickel, having the composition (Fe, Ni) S, with a varying amount of nickel sometimes reaching 35 per cent. or more. It is not easily distinguished from the pyrrhotite in which it is embedded in fresh ore, the main difference being its rather perfect octahedral cleavage, but its brassy lustre on slightly weathered surfaces is characteristic. It has not been

found in a number of the mines, probably because too finely disseminated; but at Creighton, Worthington, Evans and a few other deposits, it sometimes occurs with cleavages half an inch wide. As experiments carried out by several persons, including Messrs. Browne, Judson, Dickson and Ogilvie, have proved that with fine crushing a magnet will separate a more magnetic part with little nickel from a less magnetic part rich in nickel, it seems probable that most if not all of the nickel is contained in pentlandite, which is non-magnetic, and that the pure pyrrhotite would be found to contain little or no nickel.

Iron pyrites in both its varieties is not infrequent in the ore deposits, sometimes as distinct octahedral crystals enclosed in pyrrhotite, sometimes in larger quantities with no crystal forms and belonging to the variety marcasite. In the latter case it may contain a considerable percentage of nickel, as near the Worthington mine.

Several other compounds of sulphur and arsenic with iron and nickel occur in the deposits, but in such small quantities as to have no importance as ores, so that they may be left for consideration to the chapter on the minerals of the nickel region

RELATIONS OF ORE TO ROCK

It has already been stated that the Sudbury ore deposits are all connected with a single sheet of eruptive rock or its offsets, but it will be well to discuss the relations of ore to rock more in detail, since this has a very practical bearing for the prospector and miner as well as great theoretic interest for the geologist and mining engineer.

Prospectors long ago recognized that the ore is always associated with a particular kind of rock, diorite as it was generally called, though the work of von Foullon, Prof. Walker and others has proved that it is norite, a variety of gabbro, in which a rhombic pyroxene is important. On the ordinary weathered surface of the rock so easily attacked a sulphide as pyrrhotite practically never shows itself, being completely oxidized to limonite, whose rusty brown color is very characteristic. In the field, therefore, it is the burned-looking rock covered with gossan which attracts attention, and this has been so carefully sought for that every patch of it surrounding the nickel eruptive has been taken up by prospectors. The gossan varies in thickness from a mere film to deposits of limonite several feet thick, and almost important enough to be worked as iron ores. It is only where an impervious sheet of till has covered the fresh rock surface that the sulphides are still found fresh, and I have observed this only on a finely polished and striated surface at the Creighton mine, now completely removed. Even in the few years since mining began, the older strippings and the waste rock have been so weathered that fresh material can no longer be seen, and large fragments must be broken to show the unchanged sulphides.

In crossing the eruptive from the acid edge toward the basic edge little rusty holes like "pock marks" are the first indication of ore, and they may occur half a mile or rarely even a mile from the actual edge, with rock surfaces free from spots between. As the basic edge is approached, in most cases the spots are closer together or form blotches which unite into a sheet of gossan over ore bodies at the margin of the eruptive and for a short distance beyond over the country rock.

Ore bodies are not found everywhere along the basic edge, though one may walk for miles along that edge in places without an important break in the rusty band. There are however a few places along the circumference near Windy lake and toward the northeast of Morgan township, in the northern range, where no gossan or only a few of the pock marks are found, so that the distribution of ore is evidently very unequal. It will, of course, be understood that gossan does not everywhere mean an ore deposit of workable size, though a large area of gossan has nearly always been found to indicate an ore body worth developing.

The most satisfactory places for the study of the relations of ore and rock are naturaly the mines, and a number of geologists from various coutries have examined them with this point in view, most of them agreeing that ore and norite were parts of the same molten rock from which the ore segregated toward the edge; though a few think that the ores have been deposited by hydrothermal means by replacement of the rock-forming minerals of the norite. The evidence in favor of the theory of magmatic segregation is excellently given by Dr. Barlow in his report on the region.[16] The idea that ore bodies could be formed by the slow separation of the heavier materials at the edge of a molten rock mass was elaborated by Prof. Vogt of Christiania for the nickel ores of Norway, which have similar relationships to ours; but at about the same time Dr. Barlow expressed the same view of the Sudbury deposits, stating in 1891 that "the ores and the associated diabase were therefore in all probability simultaneously introduced in a molten condition, the particles of pyritous matter aggregating themselves together in obedience to the law of mutual attraction."[17] Dr. Adams applied Vogt's theory to the Sudbury deposits. Prof. Walker has supported the same explanation of the relationships, and the late Prof. Stetzner of Freiberg in Saxony in a letter to Mr. G. R. Mickle in 1892 makes the following statement as to these ores:

"Polishing one side of rather large pieces gives very pretty results. In the ore from the Vermilion mine one sees plainly—much more plainly than on the surfaces of fracture—the intergrowth of pyrrhotite, chalcopyrite and characteristic yellow lamellae which might be either millerite or polydymite. Morover on a polished surface like this the black rock inclusions in the sulphides show up plainly. The true nature of these inclusions and their relation to the ore is disclosed by the sections. One sees then that these black rock inclusions in no way are sharply divided from the sulphides but are connected with them by quite gradual transitions. Those of the Vermilion ore consist of quartz, brown mica, chlorite, hornblende and some epidote; those of the Murray ore of triclinic feldspar, augite, which is more or less decomposed, some brown mica and epidote. The intergrowth with the ore is such an intimate one that I cannot regard the black specks as fragments enclosed by the ore, but can see in them only formations which are of the same age as the ore. Similar relations of ore and country rock occur also in the Norwegian pyrite and in the pyrrhotite."

On the other hand there have been a few who oppose this theory, such as Posepny, who thought the presence of metallic sulphides in the magma of a molten eruptive rock an impossibility;[18] and H. W. Hixon, manager of the Victoria mines, who appears to share Posepny's view.[19] Dr. C. W. Dickson is one of the latest defenders of the theory of aqueous deposition, and his summing up of the points which favor that theory is probably the best that can be made.[20] He seems however to have been singularly unfortunate in the choice of his material for study, since he has selected almost without exception the brecciated rock material enclosed in the ore, and judging by his photomicrographs and descriptions, has not studied the opposite phase in which the norite is thickly speckled with the ore particles. Descriptions of such specimens will be given later under the chapter on petrography.

Dr. Dickson believes that almost all the evidence favors the work of water as the means of deposition of the nickel ores, but in this he is almost alone among the geologically trained students of the region, and is apparently opposed to the views of Prof. Kemp in whose laboratory he studied.

My own work convinces me that the theory of magmatic separation accords best with the facts, but that there has been some subsequent re-arrangement of the ores by solution and re-deposition in all the ore bodies, this being much more marked in offset deposits than in marginal ones. Many of Dr. Dickson's examples are from offset deposits, and naturally enough for one who had but a short time for field work in the region, he does not distinguish their characters from those of the marginal deposits, which point more clearly to an origin from the molten norite.

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16 G. S. C., Vol. XIV, Part H, pp. 123-132.
17 Ibid. 1890-91, 128 S; also Ottawa Naturalist, 1891.
18 Genesis of Ore Deposits, p. 146.
19 Geol. Sud. Dist., Eng. Min. Jour., Dec. 29, 1904, p. 1022.
20 Trans. Am. Inst. Mining Engineers, Vol. XXXIV, pp. 25-65.

Points favoring Magmatic Differentiation

Although the mode of formation of these and similar ore deposits has been widely discussed from various sides, so that most of the arguments for and against their igneous character have already been presented, the question is of so much interest that it is desirable to cover the ground once more; and to begin one may ask the defenders of the hydrothermal solution theory what is the real source of sulphide ores? The warm circulating waters must have obtained them from rocks of some kind, and at no very great depth, for open fissures are not possible at depths of more than a few miles. We know that the sulphides of the schists underlying the nickel eruptive are only slightly nickeliferous, and that the probable source of the ore must have been some heated mass of eruptive rock. If the original sulphides were obtained from a hot eruptive rock, they must have formed part of that magma, for there is no other source possible.

It has been shown there is reason to believe that the sheet of nickel eruptive is a mile and a quarter thick and that it is covered by about two miles of sediments, so that in the beginning its lower side, where the ores occur, must have been more than three miles below the surface. What theoretical improbability is there in supposing that the sulphides everywhere associated with the norite were an original part of the molten magma? If the solutions were obtained from molten, or at least heated, eruptive rock at a few miles depth, why should not such an eruptive as the nickel-bearing sheet more than three miles down bring the sulphides with it? This should be sufficient answer to Posepny, who believed that sulphides could not form part of a molten rock. We know that sulphides do form parts of such rocks, and there seems no inherent reason why from a mile and a quarter's thickness of magma sulphides enough to make the nickel deposits should not separate out, probably helped by gravitation.

The arguments for magmatic segregation in the Sudbury district may be given briefly as follows:

1. The ores are everywhere associated with the norite of a single eruptive sheet. No ore occurs without norite. No long stretch of the lower edge of the norite or its dike-like offsets is entirely devoid of ore.

2. Norite and ore are mixed in every degree from rock enclosing scattered particles of ore, to pyrrhotite-norite in which ore and rock are in equal amounts, and finally to almost pure ore with a few rock-forming minerals scattered through it. This relationship is found at every mine. Norite spotted with ore is sometimes found in bands a long distance from the nearest ore body and separated from the basic edge by rock free from ore.

3. The adjoining rock, granite, gneiss, greenstone or graywacké, is never spotted with ore, and separated bodies of ore are never enclosed in it, but veinlets of ore may penetrate the country rock, and almost always blocks of it are enclosed in the ore. The shattering and crushing of the country rock took place when the nickel-eruptive forced its way between the upper sediments and the lower crystalline rocks, and the heavier and probably more fluid sulphides filled all the spaces thus opened. There are often clean walls of country rock against large bodies of pure ore.

4. The freshest norite is generally close to the ore bodies and is often shotted with ore. The best preserved hypersthenes at the Murray, Creighton and Gertrude mines are in sections containing sulphides and not in specimens free from sulphides at a distance from the mines. No considerable amount of re-arrangement caused by water could have taken place without changing so susceptible a mineral as hypersthene into secondary minerals.

5. The marginal ore bodies show hardly a trace of hydrothermal or pneumatolytic action. There are seldom any of the minerals usual in deposits formed by water except very small quantities of quartz and calcite, and these are often in seams cutting the

ore and evidently of later formation. There is no banding such as one finds where cavities are filled with minerals deposited from solution; nor are there concentric structures about the rock fragments enclosed in the ore.

6. The deposits are extremely uniform, as shown by Dr. Barlow, a fact hard to account for in mines scattered along a length of 35 miles with entirely different country rocks on one side unless they have had a single source, the norite, which is as monotonous as the ores themselves.

7. The largest ore bodies are where bays of the norite project into the country rock or on offsets from such funnel-like bays; there is seldom a deposit of importance along a straight margin; and no ores are found on parts of the margin which project inwards instead of outwards. This is intelligible if the ore settled into the hollows under the molten sheet, but quite unaccountable if it was brought in solution from elsewhere along the channels furnished by the contact.

While the whole of the ore belonged originally to the magma of the eruptive sheet, some parts of it have been dissolved and re-deposited in all the mines, for instance in fissures in diabase dikes which cut the ore bodies; and the process of re-arrangement is more marked in offset deposits than in marginal ones. In them there are often small quantities of quartz and carbonates probably deposited by water. Finally there are a few deposits accompanied by little norite and containing arsenical compounds, nicolite and gersdorffite, such as the Worthington and Vermilion mines, which may have been formed principally through the action of heated water circulating along fissures at distances, sometimes miles, away from the edge of the great eruptive sheet.

TYPES OF ORE DEPOSITS

The Sudbury ore deposits have been described in various ways by different observers, as veins, or stockworks, or lenses, and there are examples that suggest all of these forms, though none of them seems really characteristic. Vein-like deposits with continuous well defined walls reaching for any distance are unknown, though a small outcrop of ore southwest of Copper Cliff somewhat suggests a vein. The brecciated rock enclosed in ore and the narrow seams of ore projecting into the country rock found at many mines, such as the Mount Nickel and Blezard, have some of the usual features of a stockwork, but this arrangement of rock and ore, though more or less present at the edge of the underlying country rock at all the mines, is not the most prominent feature, since it often passes into solid ore with hardly any rock at the larger mines. The term lens also is not entirely appropriate, since it implies a deposit thicker in the middle and narrowing in each direction, with fairly definite walls of country rock, conditions seldom found in the nickel district. On the whole then none of the names mentioned seem entirely suitable, and it is hard to suggest a good general term for the deposits.

Looking at the nickel ranges in a broad way two or three types of deposit seem pretty distinct, as suggested in a former report of the Bureau of Mines;[21] and this accords fairly well with Dr. Barlow's treatment of the question, since he also makes three types, though with somewhat different definitions.[22] The types of greatest importance may be spoken of as Marginal Deposits and Offset Deposits.

Marginal Deposits

The marginal deposits are found at the basic edge of the eruptive sheet along the contact with the underlying rock, and so have to the southeast on the southern range and to the northwest on the northern range a wall consisting of the older rocks, gneiss, granite, greenstone or graywacké. This is generally, however, very uneven and irregular, especially on the southern range, and often modified by faulting. On the northern range,

[21] 1903, pp. 278-280. [22] Geol. Sur. Can., Vol. XIV, Part H, p. 120.

as at the Levack mines, the gneiss of the foot wall dips southeast at from 20° to 40°, and the ore follows it as an irregular sheet. On the southern range the underlying rocks have generally been a good deal shattered and faulted, so that there is less regularity, the foot wall, if it may be so called, being rugged and much broken up, but having in the main northwestward dips of 40° to 60°. Fault planes, as at North Star, may, however, provide a well marked foot wall with a steep dip of 65° to 80°.

On the inward side toward the norite there is seldom anything which can be called a wall, unless some faulting has occurred, and the ore deposit practically blends into the norite, work being stopped in that direction when the mixture of ore and rock becomes too poor to exploit.

The marginal deposits then are irregular sheets of ore penetrating slightly and enveloping fragments of the foot wall and fading out on the hanging side into norite with too little ore to be workable. They always dip inwards toward the axis of the syncline. They may have any thickness from a few feet of solid ore with a corresponding thickness of mixed ore and rock to 250 feet of pure and mixed ore in all; and the length is equally variable but usually several times the thickness, in the case of the Creighton mine reaching several hundred feet. In fact one deposit may be connected by a fringe of ore along the edge of the norite with another a quarter or a half mile away, as the Murray mine is connected with the Elsie. How deep the ore bodies go on the incline in unknown, since the deepest workings are not beyond 172 feet (at the Blezard mine), though diamond drilling proves that the Creighton ore occurs at a depth of 400 feet, and its great open pit reaches 140 feet. Theoretically there is no reason why these ore bodies should not extend downwards indefinitely if the basin-shaped depression of the country rock continues, and it would be most interesting to have a few drill holes sunk at some distance in from the basic edge where an important deposit occurs in order to test the matter.

The marginal deposits include the Creighton mine, which may safely be called the greatest nickel mine in the world, having already produced probably more than 500,000 tons of rich ore, and, as it is supposed from the results of diamond drilling, having millions of tons in reserve.

Offset Deposits

Offset deposits occur on dike-like projections from the basic edge of the norite, and the type will be considered to include isolated ore bodies on small outcrops of norite which represent the continuation of an offset after a short interruption, in this respect differing from Dr. Barlow's classification, in which the separate ore bodies are put in a third type. In general character the ore bodies in isolated outcrops of the norite differ hardly at all from those on the dike-like projections from the main range, and we may safely assume that there are or were channels connecting them with it, either beneath the surface or above the present surface, through rocks which have since been eroded away.

The offset ore bodies are as irregular in form as the marginal ones, but they do not often show the one-sided arrangement forced on the others because of their position between the overlying norite and the underlying country rock. Often they are rudely cylindrical or oval with an elongation in the direction of the offset, and where the offset is narrow they may in places fill almost the whole width to the more or less complete exclusion of the norite. They are apt to occur at the end of a norite offset or where there is some obstruction of the channel, and very large chimney-like masses of ore may be found in small outcrops of norite, as at Copper Cliff or Stobie.

The best known of this type of mines is the Copper Cliff, where an irregularly oval body of ore, split in the lower part by a horse, has been followed down 1,000 feet, with an average width of 50 to 90 feet in one direction and 75 to 200 feet in the

opposite one. The cylinder dips at an angle of 77½° toward the northeast. The neighboring mine to the north, No. 2, has also a cylindrical shape, but its section is much greater, about 120 by 230 feet, and its known depth only 400 feet. This ore body is nearly vertical with a slight inclination to the west.

The Stobie mine is an example of a very irregular offset deposit, large bodies of ore being loosely connected with one another at various levels. More than 400,000 tons of ore have come from it, and it is said to be far from exhausted.

In a general way, the offset deposits show the same mingling of ore and rock observed in the marginal deposits, fragments of country rock of all sizes being enclosed in ore, and intimate mixtures of ore and norite occurring on their rock dumps; there are however more evidences of the action of water, such as quartz and carbonates in small amounts, and even traces of other sulphides such as galena.

There should perhaps be a third type of ore deposit defined in which little or no undoubted norite is found and so much evidence of pneumatolytic action that its formation should be considered due almost entirely to the action of water, though the materials were derived from the norite. This division might include the Vermilion mine and possibly also the Worthington and one or two others in the same region.

A good deal of confusion has resulted in the past from the non-recognition of the difference in type of the two chief kinds of ore deposits, and Dr. Dickson's work, which appeared since the distinction had been made by the Bureau of Mines, is seriously injured by not observing it. To draw inferences from the earlier worked chimney-like ore bodies near Copper Cliff, with their nearly vertical attitude, relatively small amount of much altered norite, and considerable exidence of water action, and apply the results to the marginal type of deposits in quite unjustifiable; and can only lead to error.

THE SOUTHERN RANGE IN DETAIL

The special work done in the Sudbury district has naturally been the examination and mapping of the nickel ranges and their associated rocks, and this has been carried out in detail at the various nickel mines of the region, the parts of the area which are less important from the economic side receiving less attention. As our work focussed mainly on the basic edge of the nickel-bearing eruptive and its offsets, the only parts where valuable ore deposits have been found, it will be convenient to follow the basic edge of the eruptive in detail, describing the ore deposits and adjoining rocks and referring to the results of mining operations. The acid edge of the eruptive will also be sketched with its associations, but in a more summary way. As it has been found that the width of the eruptive has an important bearing on the number and size of ore bodies it is advisable to take up both edges of the sheet, the upper, or acid, as well as the lower, or basic, edge in order to give a complete account of the ranges.

Our work has proved that in reality the outcrop of the nickel-bearing sheet is continous round the whole basin, though hidden for a distance by gravel plains toward the southeastern corner, yet the custom of the region divides the known ore deposits into two ranges, the main or southern range and the northern range, and it will be convenient to follow this usage. We shall begin at the southwest end of the boat-shaped basin and work northeastwards along the southern range, and afterwards take up the northern range in a similar way. The ranges will be looked on as continuous, the norite edge being followed the whole way, though sometimes for miles no ore bodies are known to exist along it. The offsets will be described along with the main ranges, so as to give the relationships in the most comprehensive way, though in many cases the actual physical connection between the two may not be apparent on the surface.

It need hardly be said that the present nickel-bearing rocks are only a remnant of a sheet which formerly extended more widely in all directions and perhaps covered

more than double its present area. That weathering and erosion have destroyed hundreds of cubic miles of the rock and millions of tons of the ore is evident from the present arrangement of things at the truncated edges of the sheet, so that we can now examine the condition of affairs at a depth of at least two or three miles below the original surface of the country. In the beginning the basic edge of the southern range was covered by the overlying eruptive sheet to a depth of nearly two miles, and above this we may suppose that the sediments of the Trout lake conglomerate, Onaping tuff, Onwatin slate and Chelmsford sandstone, reached a thickness of two miles. It is then the basement of the region, where much fracturing, faulting and settlement went on during the excessively slow cooling of the molten sheet, that is at hand for study, and many points will be more intelligible when this is borne in mind.

Sultana Nickel Mine

At the southwest end of the southern nickel range is the Sultana nickel mine, reached from Worthington on the Sault branch of the Canadian Pacific Railway, by a road about 7 miles in length. The deposit is on lots 7 and 8 in the VI concession of Drury township, and the same lots in the I concession of Trill. The houses and office used during the development of the property stand near the corner post between the lots just mentioned; and the strippings and other workings follow the foot of the hill in a direction 10 degrees west of north for about a quarter of a mile from the corner post, so that the actual workings are in lot 8 of Trill; but one or two small outcrops occur on the hillside at a distance of 9 or 10 chains south of the corner post also. Part of the deposit is therefore in Drury, and the known extent of the ore is three-tenths of a mile. It is probable that careful search would disclose ore still farther to the south along the edge of the hill, but the bush is thick and no other hints of gossan were found.

Most of the ore to the north of the camp is along the lower flanks of the hill, but an offset runs 9 chains to the west a little north of the corner post, and two large strippings at this point show ore at the hill top 117 feet above the flat at the bottom.

There are three shafts, respectively 13, 19 and 22½ chains to the north of the corner post, and beyond the last shaft the hill turns off to the west, and no more ore is to be seen. The deepest shaft is said to be down 110 or 120 feet; and there is a considerable quantity of ore on the dumps. A drill hole sunk a little to the east of the last shaft showed 36 feet of clay and sand, then norite followed by some ore, and finally greenstone with more or less ore. The dip of the rock surface between the shaft and the drill hole is about 40 degrees to the east.

In general the ore in this locality seems to lie in depressions of the hill as if it had settled into the lowest places. As the rocky hills bounding the swampy valley to the east and west seem to be converging toward the south, it is not unlikely that ore may be found beneath the swamp or drift in that direction, but up to the presnt none has been reported; nor is it known if an offset runs southwards into Drury township.

The rocks forming the hill west of the gossan are not Laurentian, as suggested on the old maps, but are more like Huronian, since they include green schist and diorite, with irregular patches of what appears to be norite penetrating them and showing on the flank of the hill toward the low ground. Much of the hill has the look of crush conglomerate.

The norite north of the Sultana is greatly mixed with older rocks, especially a flesh-colored arkose, and for half a mile in that direction, if it were not for the finding of the basic edge near the mine and the acid edge still farther north, one would be in doubt as to the relationship. There was a great amount of crushing and faulting of the older rocks with the eruptive toward this narrow southwest end of the boat-shaped trough; but the thickly wooded surface prevents a very complete study of the geology. Just west of the Sultana mine the boundary of the norite is hard to trace, but about a mile to the northwest it is clearly seen again not far from a wagon road, now fallen

into ruin and grown up with bushes, on the way to the Trillabelle or Gillespie mine, and there appears to be a small bay of mixed Laurentian and Huronian projecting into the eruptive to the north of the Sultana.

To the east of the hill along whose slope the Sultana ore is found a wide swamp stretches across the valley toward what is called the Sultana East property, where gossan shows on a hillside facing northwest and runs round the end of the hill just within the township of Trill, and then enters the VI concession of Drury in lot 7, running a little south of east into the next lot. The hillside dips away into a swamp to the north, and gossan with small pits showing ore extends for about 230 yards. Between the outcrops on each side of the valley one low hill of gray norite rises above the muskeg, but no ore has been found there. The country rock of the Sultana east is greenstone mixed with coarse gabbro or anorthosite and a little gneissoid rock, so that it belongs to the Keewatin or Huronian. The northward slope of the hill, which represents the foot wall of the ore, is not far from 40°.

To the east of the Sultana the basic edge of the eruptive bends southeast, is not accompanied by ore, and consists of medium to coarse-grained norite with granite or gneiss to the south, a band of swamp usually separating the two rocks, and in lots 3 and 4 hiding the contact altogether.

The Chicago Mine

A mine variously called the Chicago, or Travers, or Inez, in lot 3, con. V of Drury township, is the next point where ore has been found. It is reached by the road from Worthington mentioned before and was formerly connected with the railway at that point by a curious overhead tramway with only one rail, from which buckets were suspended and drawn by horses.

The mine is on an offset at a distance of about a quarter of a mile from the basic edge, Laurentian appearing between, while the ore is enclosed in a very mixed Keewatin or Huronian rock consisting of greenstone, green schist, porphyrite and anorthosite. The workings include a small open pit and a shaft reaching a depth of 160 feet, and the pockets of ore do not seem to have been large, though some thousands of tons were roasted and smelted to matte at the mine, the products being trammed to Worthington and shipped away.

The houses connected with the mine are placed some distance to the north of the shaft house and smelter, near the basic edge of the eruptive, which consists of coarse gray norite.

Acid Edge in Trill and Fairbank

The acid edge of the nickel-bearing eruptive is best studied form a succession of small lakes which follow its margin and give good sections of its contact with the conglomerate and tuff. The edge runs north and south across Ross lake and an unnamed lake half a mile to the south, then turns east to Cameron lake, and continues east to the northwest corner of Fairbank lake. From Cameron lake to Sultana mine the eruptive is only two miles wide, but at Fairbank lake the width increases to four miles. Near the unnamed lake, and also Ross lake, the boundary rises as sharp hills nearly 300 feet high, and the sedimentary rocks seem to have been much crushed and faulted, probably because of the narrowness of this end of the basin. The basal conglomerate is prominent with very large granite boulders, and coarse white quartzite, dark gray cherty rock, and hardened tuff occur somewhat mixed with felsitic looking rocks. The acid edge itself consists of fine-grained dark greenish, schistose, material which is far from suggesting syenite or granite, but really consists mainly of micropegmatite.

The north shores of Fairbank lake are formed of the same dark green schistose phase of the acid edge, while farther south there are dark reddish syenitic looking rocks followed by gray norite south of the lake to the Chicago mine.

After touching the northwest bay of Fairbank lake the acid edge first runs eastwards and then northeast to Gordon lake, and at a peninsula toward its east end bends southward for fully a mile, after which it turns northeast once more from about the middle of lot 4, con. II, in the township of Fairbank. The boundary between the acid eruptive and the conglomerate is often very indistinct along this sharp southward bend, bands of rock without pebbles alternating without regularity with parts crowded with pebbles, the whole forming a belt a mile or more in width. The strike of the schistose structure, which is well marked in the acid edge as well as in the rolled out conglomerate, is 65° or 70°, and not parallel to the direction of the eruptive contact, a feature very seldom seen elsewhere in the basin. The dip of the schistosity is about 45° to the southeast; but the dip of the stratification, as somewhat vaguely shown by bands crowded with pebbles and boulders, is 25° or 30° to the N. W. It is likely that the great width of the conglomerate in this part is due to a flattening of the dip caused by faulting in the Archean supports of the eruptive sheet near Vermilion mine, as will be noted later.

The Victoria Mine Region

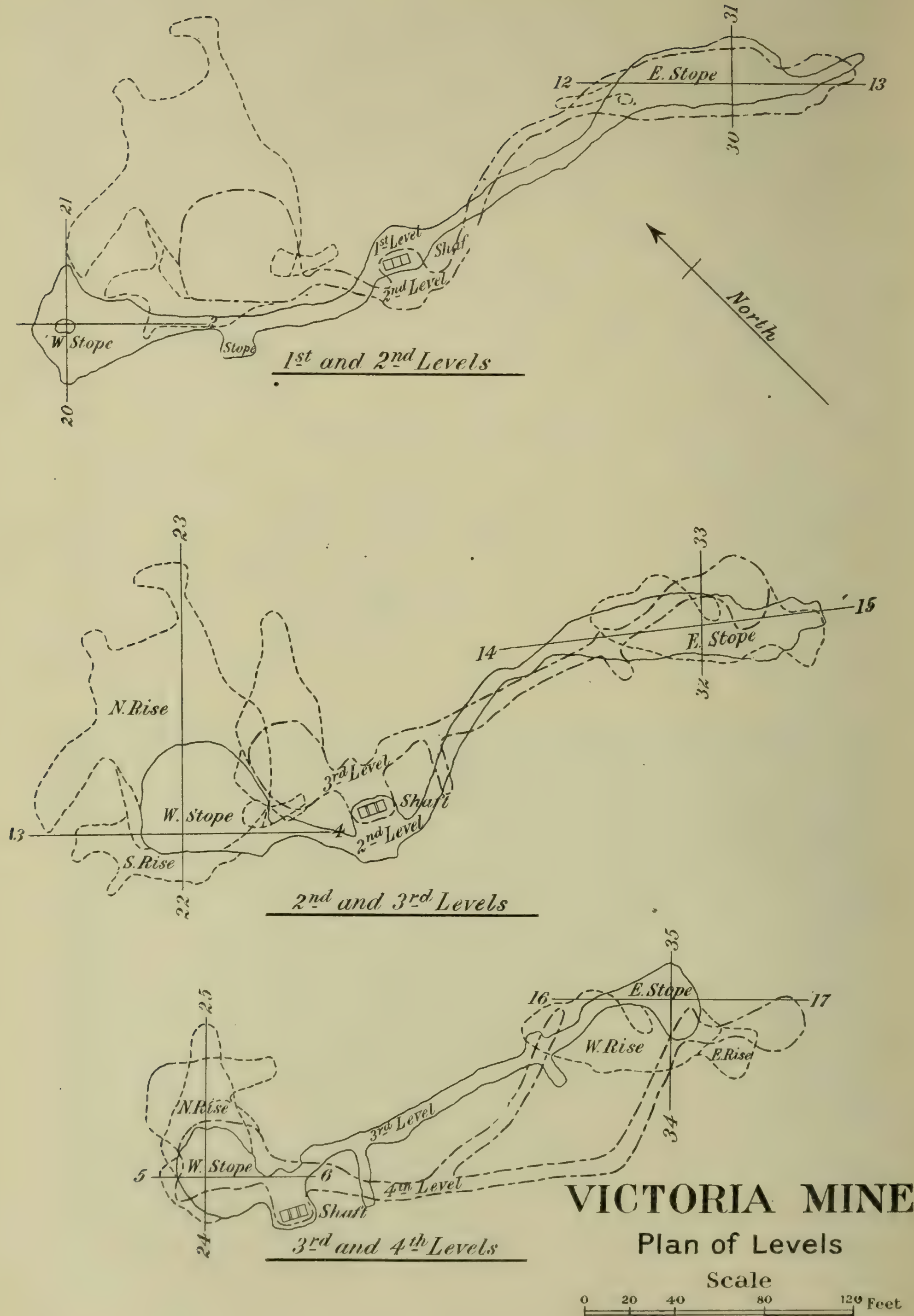
Returning to the basic edge of the eruptive, it may be followed east from the Chicago mine to the boundary of Denison township, where for some distance it disappears under drift materials. The most westerly ore deposit in the township is in the south half of lot 11, con. V, or perhaps the north half of the same lot in the IV concession, the boundary lines being almost impossible to follow in this township. There are two large pits and several smaller openings or strippings disclosing a good deal of mixed ore, which lies against a hill of greenstone and green schist. To the north the low ground is largely swamp, but some coarse-textured norite occurs, sometimes crushed and sheared into conglomerate or squeezed into schist.

Victoria Smelter.

The schistose rock to the south has a dip of 70° or 80° to the south, and not far from the ore deposit there is a large quartz vein running parallel to the schistose structure. This has been mined to some extent to provide the silicious lining of converters at the Victoria smelter.

The basic edge turns northeast for a mile beyond this opening, though the boundary is mostly hidden under swamps, and then southeast to Victoria mine on lot 8 in the IV con. of Denison, much the most important mine in the western part of the

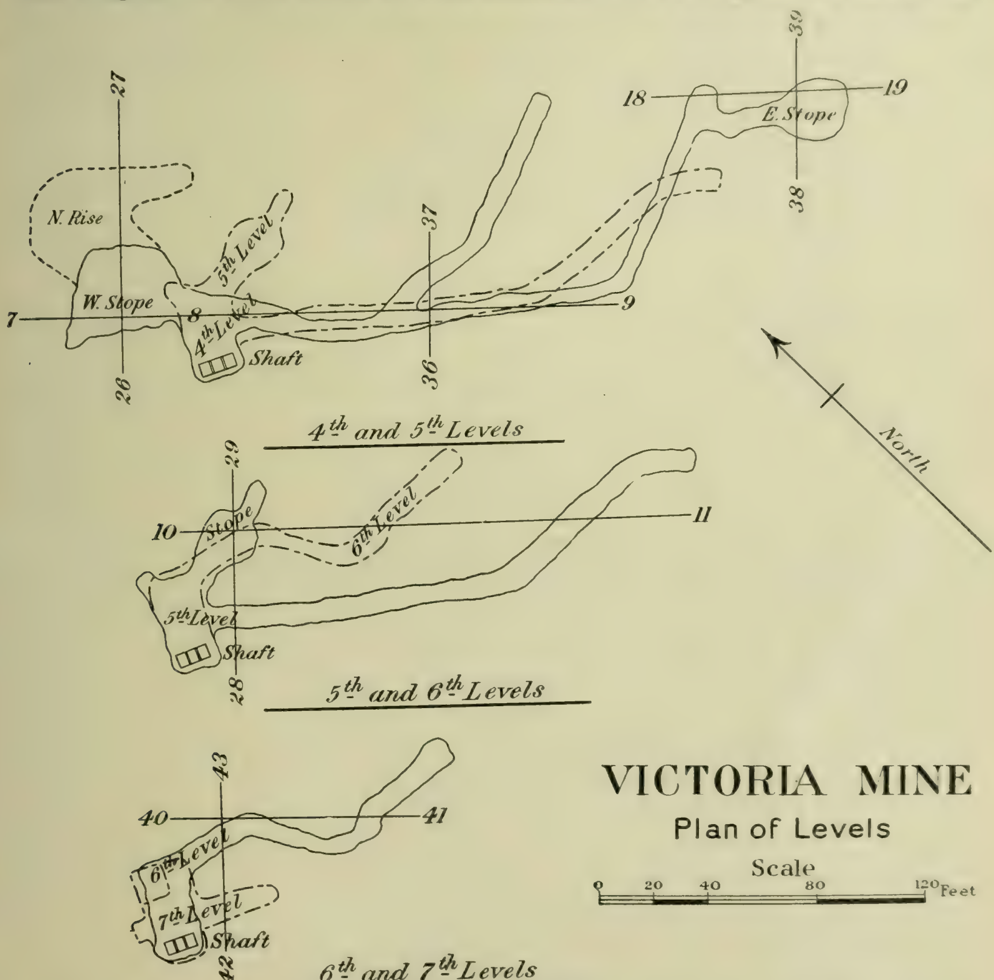
southern nickel range. At Victoria mine a long offset starts to the south and southwest including the Worthington mine, and another shorter one toward the southeast to the Vermilion mine; but both are more or less discontinuous, narrowing and widening or disappearing for a time altogether, so that they are hard to follow. The basic edge of the eruptive turns northeast for a mile beyond the Victoria mine, so that we may consider this ore body as lying at the end of a funnel which opens into the narrow offsets just mentioned. Ore deposits or gossan are found for half a mile northwest of the mine and also for some distance to the northeast, while to the north the usual coarse gray norite stretches for a mile or two. Several of the minor ore bodies have been opened up by the Mond Company by small shafts or test pits, but the main work has been done at Victoria mine itself, where the funnel narrows to its outlet.



1st and 2nd Levels
W. Stope
Stope
1st Level
Shaft
2nd Level
E. Stope
North
2nd and 3rd Levels
N. Rise
W. Stope
S. Rise
3rd Level
Shaft
2nd Level
E. Stope
3rd and 4th Levels
N. Rise
W. Stope
Shaft
3rd Level
4th Level
W. Rise
E. Stope
E. Rise
VICTORIA MINE
Plan of Levels
Scale
0 20 40 80 120 Feet

The country rock to the southwest and southeast consists of various greenstones, such as diorite, hornblende porphyrite, and green schist, followed by chloritic slate interbanded with quartzite, and all these rocks appear on the dump at the mine, as well as fine-grained gabbro and actinolite rock probably resulting from its alteration.

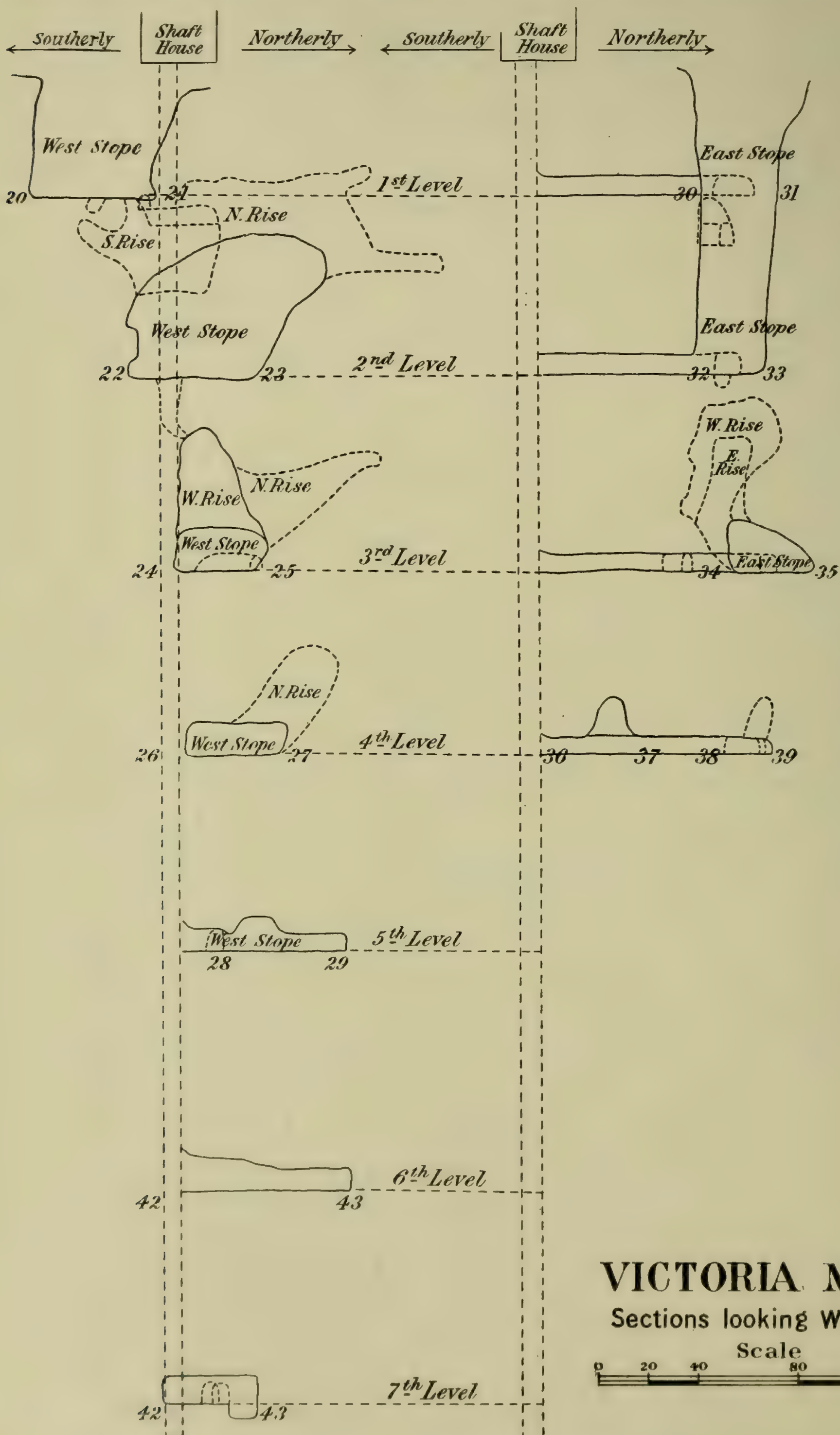
There are two large open pits near the shaft house, showing the rocks just mentioned, but mining is now being carried on by a shaft which reaches a depth of nearly 560 feet, and the ore is known by the results of diamond drilling to continue to 750 feet from the surface. As will be seen from the accompanying plans there are two somewhat irregular ore bodies worked from the same shaft. The arrangement of the deposits



of ore at Victoria mine is quite different from that which has been referred to at Sultana mine, since they occur apart from the main body of norite at the beginning of a narrow offset, so that neither wall of the ore bodies is of norite. In nickel ore deposits of this kind the dip approaches the vertical, while in the other kind it may be 45° or less, the ore resting on the Archean as a foot wall and blending upwards into the norite. The sides of the funnel to the northwest and northeast of the mine slope at an angle of about 45° into the swamp, or an artificial lake used as a water supply, and the gossan upon them represents ore bodies arranged in the marginal way, as contrasted with the main ore deposits at the mine, which are offset deposits.

This mine has already furnished a large amount of ore, and is far from being worked out.

The offset beginning at Victoria mine runs southeast for a quarter of a mile, as shown by two small hills stained with gossan, and then bends southwest toward Worth-



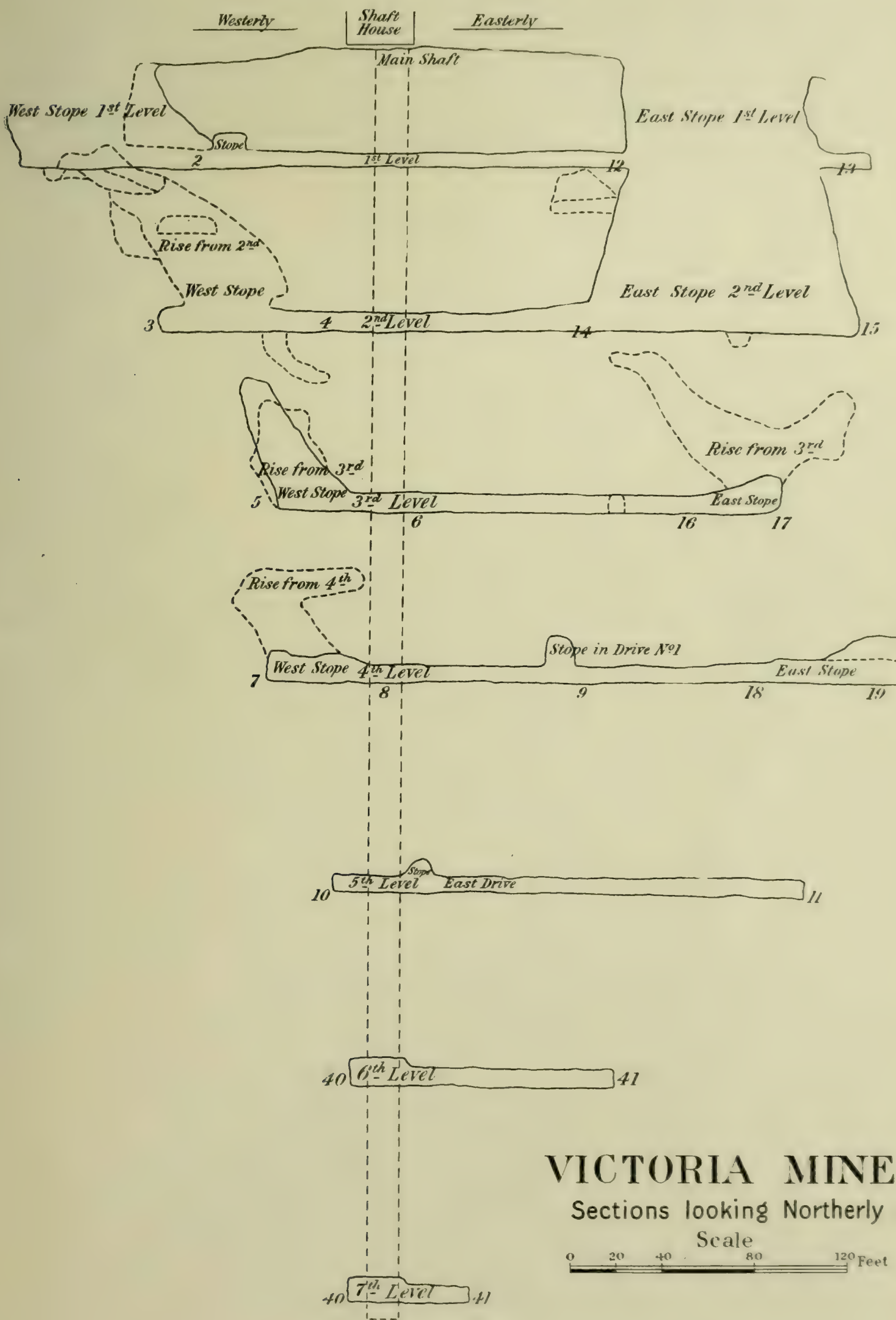
VICTORIA MINE

Sections looking Westerly

Scale

0 20 40 80 120 Feet

iugton. It probably forks at the second hill, forming perhaps a subterranean con nection with Vermilion mine to the southeast.



VICTORIA MINE

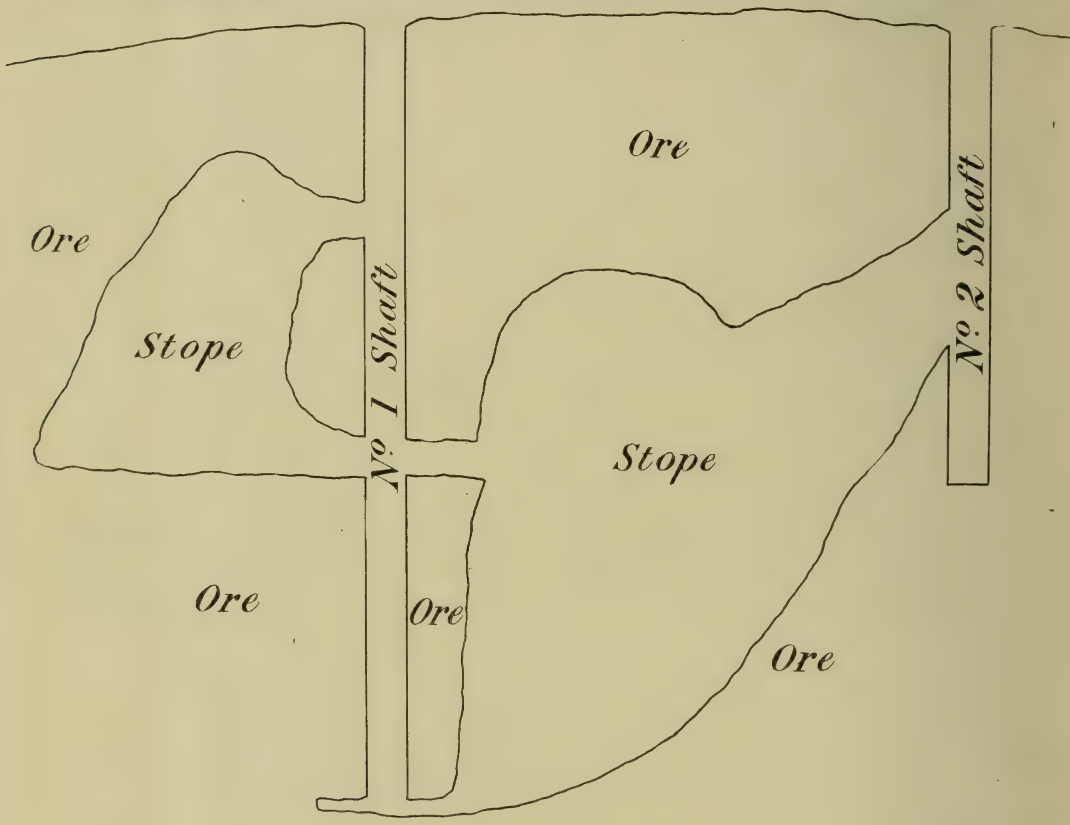
Sections looking Northerly

Scale

0 20 40 80 120 Feet

The Worthington Offset

The branch running southwest has been traced from the middle of lot 8, con. IV, in Denison township, to lot 3, con. I of Drury, a distance of 4½ miles, and probably extends a mile farther. The first part, as far as a swamp north of a small lake in lot 12, con. III, shows fine-grained norite more or less rusty, but with little ore; but beyond this small ore bodies have been found at various points, such as the O'Connor shaft, the Robinson drift, and the Totten mine, where a small shaft has been sunk. Here a broad band of diabase cuts the offset, but the rusty norite with small pockets of ore continues beyond and culminates in the Worthington mine, which several years



WORTHINGTON MINE

ago produced some thousands of tons of the richest nickel ore in the district. A quarter of a mile to the southwest is the Mitchener or Hamilton mine, and beyond this the band of rusty norite can be followed with certainty to a small lake near the southwest end of lot 3, con. I in Drury. On the other side of the lake rusty patches can be traced for some distance into the township of Lorne, but no undoubted norite is seen, quartzite, with some outcrops of greenstone being the rocks observed. There are patches of crush conglomerate along this line which may represent the fissure occupied by nickeliferous norite at Worthington and Victoria mines.

At the Mitchener mine the fine-grained norite is quite distinct, and is in a sense the matrix of a crush conglomerate containing angular or rounded masses of the

adjoining rocks, graywacké, quartzite, greenstone, etc. The norite has the characteristic spotting with blebs of ore, and a shaft has been sunk on a small deposit of solid ore.

The Worthington mine has not been worked for over eight years, and the geological relationships are not well displayed, but a small amount of rusty norite and rocks similar to those at the Mitchener mine are found on the dump, as well as actinolite. The norite masses are sometimes spotted with ore as in almost all nickel mines. The minerals found at this mine include pentlandite, niccolite and gersdorffite, three rich compounds of nickel, accounting for the high character of the ore; and the same minerals occur with pyrrhotite and chalcopyrite at several of the small pits and shafts to the northeast.

The Vermilion Mine

The other branch of the Victoria mine offset has not been traced, but the extraordinary ore deposit at Vermilion mine on lot 6, con. IV in Denison township, a mile to the east, evidently belongs to the nickel range, and so must be connected in some way with the rest of the deposits. This mine, with the Victoria mine, are marked out from all the others by containing in considerable quantities free gold and sperrylite, the arsenide of platinum. From a shaft 60 feet deep at Vermilion mine the richest ore in the district has been extracted, but the ore bodies are only small pockets, and may not prove of great value in spite of their high contents of nickel and copper and the gold and platinum they contain.

The rocks enclosing the ore are varied and do not include any typical norite, though a gray-green gabbro occurs and also rock spotted with ore. It is probable that these unusual ores reached their present position in large part by aqueous means rather than by the flow of molten sulphides and rock; but the final solution of the problem must be left till more extensive mining operations are carried on.

Certain general features of this important section of the nickel range should be noticed before passing on. The whole width of the eruptive is four miles, which is about the average for the southern range; and there is an extensive bay-like recession of the acid edge toward the northeast with a corresponding projection of the basic edge toward the southwest, ending in the long offset toward Worthington, the one apparently in some way bound up with the other. The whole region south of the nickel range is greatly broken up with faults which often manifest themselves as irregular belts of brecciation such as one finds along the Worthington offset, and this is most naturally explained by supposing a collapse of the Archean floor beneath this part of the range, perhaps because of the unusual load of liquid rock resting on it, or because the source of the magma was beneath it, removing its support. The main fractures resulting from this collapse afforded irregular channels through which the lowest layers of the magma (including molten ore) were forced, making breccias with a cement of norite or of ore and starting a circulation of heated water charged with mineral solutions which penetrated beyond the bounds of the molten rock itself. The presence of unusual ores and of such minerals as quartz and calcite indicate the action of water in re-arranging or in transporting and depositing the ore bodies.

Krean Hill to Gertrude

From about the middle of lot 6, con. V of Denison township the basic edge of the norite runs nearly due east to the boundary of the township, and then northeast across the Vermilion river to Gertrude. From the gossan northeast of Victoria mine to Krean Hill in the south half of lot 5, con. V, a mile and a half northeast of Vermilion mine, there is little evidence of ore along the contact except some rusty spots in the greenstone to the south. Beside greenstone, green schist and quartzite are found along the boundary, the direction of cleavage being 50° or 55°.

Krean hill rises as a sharp slope of gossany hillside which has been partially stripped for a quarter of a mile, and has been opened up by a few test pits. The coarse gray norite contains quartz and mica, and is blotched with spots of gossan where blebs of ore have weathered out, and the gossan increases till the surface of the rock is covered. The adjoining rock is mainly greenstone, often as large or small blocks with ore between. The ore is pyrrhotite of an unusually platy kind, cleaving with surfaces an inch square A vein of quartz near the west end of Krean hill contains a little free gold, but this is no doubt later than the ore as a whole.

Patches of gossan are seen along the edge of the norite from point to point for half a mile east of the main body, but no deposit of importance is found until the township of Graham is reached, where a shaft has been sunk by Mr. William McVittie, on lot 12, con. V. The rock south of the contact is mainly greenstone to the boundary of Denison, but farther northeast largely granite and gneiss.

On the east side of the Vermilion swampy country intervenes for half a mile, beyond which the boundary runs northeast to the township of Creighton, in lot 7, where it bends to the east toward Gertrude. Along this stretch there is little indication of ore, and the rock to the south is mainly gneiss or granite, with a mixture of greenstone. In many places the actual contact is hidden by muskegs, but along the line between lots 9 and 10 in Graham norite without ore meets porphyritic granitoid gneiss. The color of the nickel-bearing norite gradually becomes darker as one advances from the west end of the southern range, and the presence of grains of blue quartz and of scales of biotite attracts attention, but the composition of the rock as seen in thin sections does not vary much; the main difference beween the extremes being the presence of dusty particles in the feldspar giving it a deeper color.

Gertrude Mine

At a small creek on lot 5, con. I of Creighton township the first of the ore deposits of Gertrude mine shows itself, where a small tunnel has been run into the hill on the east. The norite is partly coarse and partly fine-grained, forming an irregular mixture, and the ore lies against greenstone and penetrates fissures in the latter rock. From this eastward more or less gossan and norite spotted with ore extends to the main workings about on the line between lots 3 and 4 and less than a quarter of a mile north of the boundary of Creighton. There are three shafts along the line of gossan, and various open pits, the most important one being the most easterly, where a body of very rich ore has been worked out. The whole extent of the gossan is about three-fifths of a mile, and the most important ore body is where there is a slight southward embayment of the norite edge. Diamond drilling north of the open pit near the eastern shaft discloses rich ore like that from the pit, and indicates that the foot wall dips from 67° to 55° toward the north. There are 20 feet of solid ore with 15 feet of mixed ore at a vertical depth of 120 feet. The pit to the south of the diamond drill holes appears to be a separate pocket, perhaps once an upward continuation of the sheet of ore disclosed by the drill cores, separated by a fault.

The rocks to the south of the contact are largely the older norite merging into greenstone, often brecciated at the edge of the ore bodies as if some crushing and faulting had taken place there. The rocks on the dump near the open pit include norite dotted with ore, greenstone, quartzite or graywacké, and masses of actinolite, probably an alteration product of the norite, and some well-rounded pebbles and boulders of rock are enclosed in ore. In early days the ore was mainly pyrrhotite, but later workings show considerable chalcopyrite as well, and sometimes also pyrite, occasionally in octahedral forms. A little quartz occurs with the ore, and seams of quartz are found in schistose greenstone south of the contact.

To the south of Gertrude there are rather low hills of greenstone of various kinds for nearly a mile, penetrated however by dikes of granite and irregular areas of

granitoid gneiss. The latter rock increases in amount southwards, until the proportions are reversed, and the rocks may be described as granitoid gneiss with many large and small inclusions of the various greenstones. The gneiss is evidently the later rock of the two.

Just east of the line between lots 2 and 3 the edge of the norite turns north and then curves east and southeast toward a small lake at the west end of the Creighton ore body. Where the northward bend takes place there is a small offset to the south, on which some ore has been disclosed by stripping, but along the bend to the north little gossan and no ore has been seen. The rock projecting northwards here is mainly the fine-grained phase of norite, often referred to as "older norite," and greenstone, probably resulting from its re-arrangement, but there is also some granite and probably re-crystallized arkose At one point in lot 2 a vein of rusty quartz has been prospected by Mr. McVittie, who finds the ore to contain $4.50 in gold per ton.

The Creighton Mine

The most important nickel mine in the district, and one may safely say also in the world, is the Creighton; and it will be desirable to consider in some detail the character of the ore body and its relationship to the enclosing rocks. From the map it will be seen that the Creighton mine is not in Creighton township, but near the middle of lot 10, con. I of Snider, though the ridge of gossan-covered norite just to the north of the mine runs southwestward into lot 1 of Creighton. The position of the mine with reference to the margin of the eruptive is of particular interest, since it probably accounts for the unusual size of the ore body. The present great open pit is at the southeastern corner of the largest and deepest bay of the norite along the southern range, and the width of the eruptive is here at its greatest, $4\frac{1}{8}$ miles. Here also we have the greatest width of the whole basin, as measured from Creighton to the Levack mine. This bay of the norite lies between the two great southern offsets at Victoria mine and Copper Cliff, but nearer to the larger one at Copper Cliff. We may suppose that the greatest amount of the fluid ore accumulated beneath the greatest thickness of overlying magma and was caught in the extreme end of the bay, which had no funnel-shaped outlet along a plane of faulting to allow the ore to escape and push up as separate ore bodies along an offset, as we find in the two cases mentioned. The theory given here is practically the view adopted years ago by some of the best prospectors of the region, though they contented themselves with the observation that one is most likely to find a good body where the "diorite" makes these bay-like projections.

The norite to the north of the mine is of the usual kind, coarse, dark gray, and containing blebs of quartz and flakes of biotite; but in many places it is more or less mixed with strips of greenstone squeezed into schist, or masses of what appears to be diorite; and near the contact granite, porphyritic granitoid gneiss, and arkose are enclosed also. Even hundreds of yards to the north some pitting of the surface is noticed, due to the weathering out of spots of ore, and this increases till the edge of the ridge facing southeast is reached, where much of the norite and the included blocks of other rocks is covered with gossan. This is not, however, uniform, but runs in short bands parallel to the edge of the hill, one band ending and another one beginning a little above or below, suggesting a corresponding banding of the blebs of ore in the rock. At the base of the hill is a narrow strip of swamp, ending toward the east in a small lake, and the large pit is between the two. Evidently the boggy depression represents ore which has been weathered and removed.

The rock to the southeast is coarse flesh-colored granitoid gneiss, often porphyritic, containing occasionally masses of greenstone and cut by finer grained syenite or gneiss. These rocks just beyond the open pit and the swampy strip which represents the westward continuation of the ore rise little above the flat, but one or two hundred

yards beyond form steep and rugged hills much higher than the norite ridge to the northwest. The hill behind the village shows an extraordinary mixture of rocks, coarse porphyritic granite, well banded gneiss, hornblende schist, hornblende porphyrite and a medium-grained gray eruptive, the whole cut by faults which sometimes formed crush conglomerate or breccia containing several kinds of boulders.

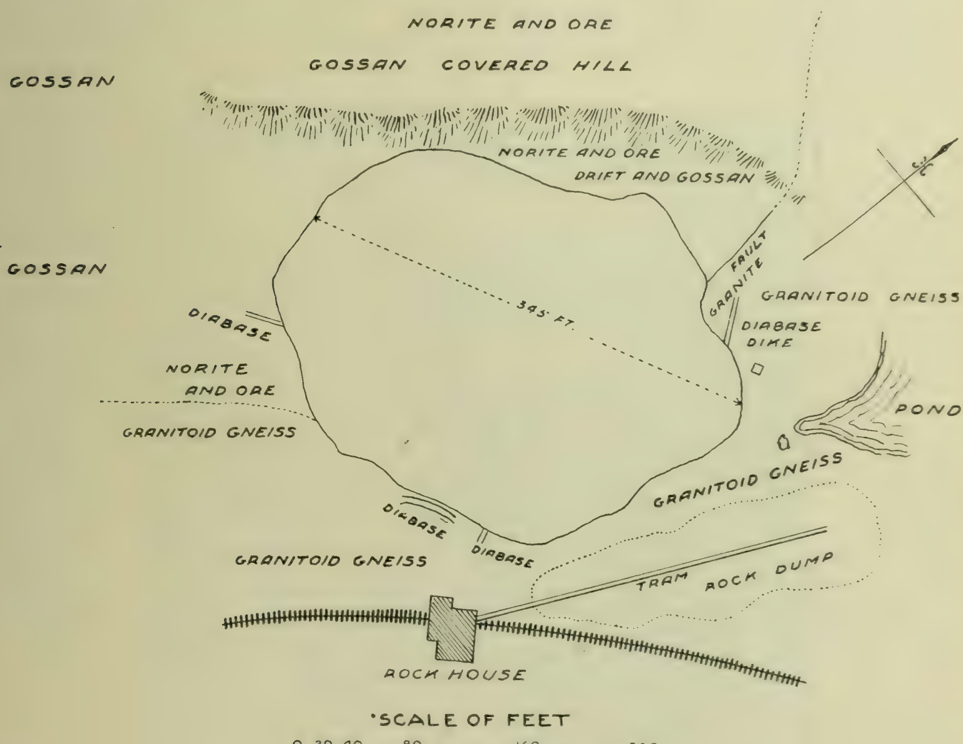
Creighton Mine, open pit, first level, August, 1904.

The great open pit of the Creighton mine affords the best opportunity for studying the intimate relations of ore and rock to be found in the region. The original pit was 60 feet deep and almost in solid ore, but as it was enlarged to the northeast, northwest and southeast more rock was encountered, as the ore body dipped northwest beneath a mixture of norite and ore. To the southeast is the irregular wall of coarse granitoid gneiss, which bends sharply in a direction a little west of north. During the past year a second level has been opened 80 feet below the first on the dip of the shaft, which is 60°, and toward the end cf the summer a beginning was made at opening up the whole pit to that depth.

The open pit shows three main types of rock, the oldest, granitoid gneiss, with a very uneven surface forming a rectangular enclosure for the ore body, next in age norite mixed in all gradations with pyrrhotite and chalcopyrite, and finally diabase dikes, often very porphyritic, penetrating in various directions gneiss, ore and norite impartially. All of the rocks mentioned have undergone more or less faulting and crushing, and fragments of the two older rocks are often enclosed in ore as a sort of breccia, but not of the diabase, though the latter also has been fractured in places and faulted in a small way producing slickensided surfaces. The dikes have a fine-grained or compact selvage against norite and gneiss, and an almost glassy selvage against ore, showing that the ore was cold when the dikes were formed, and being a good conductor chilled the surface sooner than the rocks. The ore mixes in such a way with the norite that the conclusion cannot be avoided that the two materials

existed in a state of fusion together. From norite with disseminated specks of ore all transitions are met to ore containing tiny scattered crystals of feldspar, or less often the dark minerals; and thin sections prove that the rock-forming minerals are exceedingly fresh, even the hypersthene, which readily suffers change and is completely altered to secondary hornblende in the norite north of the mine. The mixture cannot then be the result of replacement of rock minerals by ore through the action of water.

On the other hand the ore is never intimately mixed with the granitoid gneiss, though it may penetrate it a little way as irregular seams, nor is it found in the diabase dikes, except as thin films between slickensided surfaces. That the ore was there in the beginning, arriving as an ingredient of the norite is very clear, but since then certain changes have taken place on a small scale by circulating waters. Part of the faulting shown by the older rocks may be later in date than the cooling



CREIGHTON OPEN PIT JULY 1905.

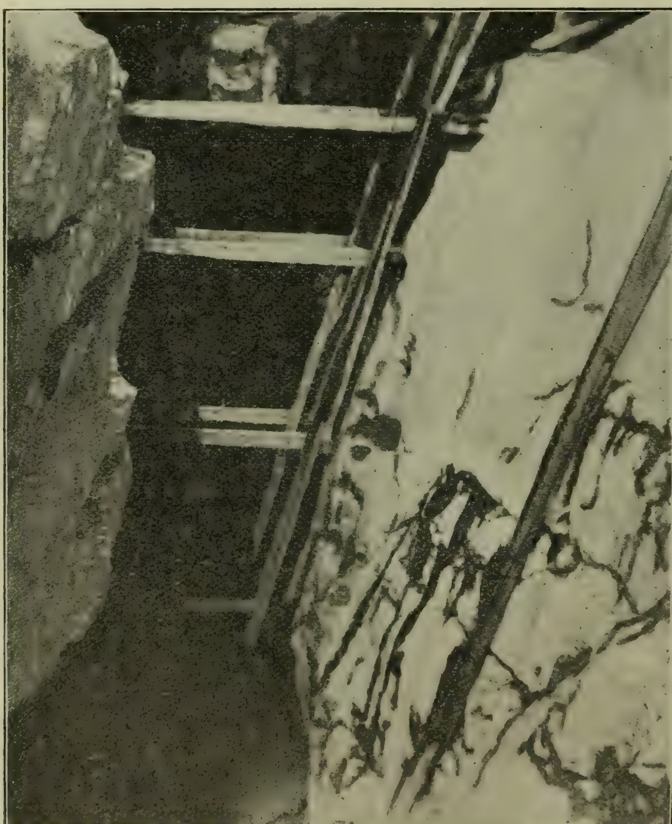
and consolidation of the ore, the latter, as the softer material, adjusting itself between the blocks. This may account for the curious "horse" of granitoid gneiss at the northeast side of the pit, which seems to have slipped down into the ore, though it might be equally well explained as slipping down into the pasty mixture of half cooled norite and ore before the final consolidation.

From the faulting and irregularity of the contact of the ore with the granitoid gneiss, it is rather hard to determine the original dip of the Archean surface over which the nickel-bearing norite spread, but drill holes to the northwest and west show that the floor dips in the main about 40° to the northwest. How far the great sheet of ore extends beneath the norite in that direction in unknown, though the results of drilling prove the existence of millions of tons. Up to the present the mine has produced

about half a million tons of ore, and for some months of the past year averaged 18,000 tons; so that it is clearly one of the world's great mines. As the ore averages 5 per cent. of nickel and 2 of copper, the great value of the mine is apparent.

North Star Mine

The boundary between the norite and the Archean runs for half a mile a little west of north from the Creighton mine, then turns north and finally northwest to the North Star mine in lot 9, con. III of Snider township. Much of the country is low and swampy and the comparatively few outcrops of rock rise but little above the general level. The rock to the east and southeast of the norite is commonly coarse granite or syenite, flesh red to gray in color, and often porphyritic and gneissoid; but patches of greenstone occur also. Comparatively little gossan is seen at the norite edge, though there are frequently rusty blotches. Near the North Star mine there is rather more of the greenstone than usual, including a small area of "older norite" like that found near Gertrude and Creighton.



North Star, open pit.

The mine has hitherto been worked as a narrow open pit, but in the summer of 1904 a shaft was sunk to a depth of 170 feet, and lower levels are being opened. The dip of the ore body as seen in the open pit and shaft is unusually high 75° or 80° toward the northwest, and the foot wall is clean cut and slickensided, probably a fault plane. Capt. Corliss reports that on the hanging wall the ore fades out irregularly into the norite until finally there is only norite flecked with ore. Some curious well-

rounded boulders, as well as angular blocks of granite and greenstone, are enclosed in the ore, and a little quartz occurs as small seams in the ore near the foot wall. At one point a horse of granite runs diagonally across the ore.

The attitude of the Archean surface where unaffected by faulting is not evident at the North Star mine, and in this respect it presents an extreme example of what has already been noted at the Gertrude and Creighton mines, where faulting, crushing and slickensiding are marked features. The ore from the North Star, when free from rock matter, is richer than the average of the southern nickel range; so that the great Creighton mine with its unusually rich ore is flanked to east and west by smaller deposits, the North Star and Gertrude, having ore of a similar grade, the smaller deposits occupying only slight embayments of the norite edge, while the great ore body was accumulated at a deep depression of the norite into the Archean substratum.

From the North Star the line of contact of the norite continues for a mile northeastwards and then bends more to the east, but no ore deposits of importance occur until the Tam O'Shanter is reached at the northwest corner of lot 5, con. III of Snider township.

The norite edge to the northeast follows close along the railway track, and is of the usual kind, though somewhat sheared and schistose in places. Except for rusty spots there is little evidence of ore. The country in this direction becomes more hilly than near the North Star, the granitoid gneiss rising rather sharply in many places from the flat country occupied by the norite.

Acid Edge in Creighton

The acid edge of the nickel-bearing eruptive to the northwest of the mines just described is best reached by Vermilion river and a chain of small lakes including lake Emma, Moore lake and Whitewater lake, with Levy creek which connects them. The canoe route is seldom more than a quarter of a mile from the contact and each of the lakes lies upon the contact, giving opportunities to observe it.

The wide and vaguely bounded conglomerate south of Gordon lake has already been referred to as running south from that lake and then turning northeast toward the mouth of Levy creek, much of the region toward Vermilion river being covered with drift or muskegs so that outcrops of the actual contact are infrequent. The conglomerate on hills west of the drift-covered shore of the river is schistose with a strike of 45° and a dip of schistosity of 50° to the southeast; but the strike and dip of the sedimentation is probably entirely different, like that observed south of Gordon lake.

On both shores of Vermilion river near the mouth of Levy creek there is a somewhat narrow bank of clay rising about ten feet, followed inland by swampy land; and the contact of the acid edge with the conglomerate is first seen a quarter of a mile south of Levy creek, and about an eighth of a mile inland toward the west. A mile inland the edge is schistose, having a strike of 70°, and the schistose conglomerate has the same width with a dip of 50° to the southeast.

The characteristic tuffs are not found for more than a mile to the northwest at some distance inland from the river, where a steep hill of slaty tuff rises from drift and swampy ground. The tuff at this point contains numerous small pebbles of waterworn materials, and the cleavage strikes 60° and dips 45° to the southeast.

On the east side of the Vermilion the rock cropping out just to the south of Levy creek is schist conglomerate, and this extends southeast for a quarter of a mile where at a small lake schistose rock without pebbles forms the acid edge. At the rapid not far above the mouth of Levy creek the rocks exposed are hardened tuff, with a dike of fine-grained granite or felsite, but the stretch between this and the schist conglomerate is covered.

Levy creek between the Vermilion river and Emma lake flows between low clay banks with a few exposures of tuff rising little above the water's edge, and excursions inland show the acid edge at about a quarter of a mile to the south. On Emma lake the boundary crosses the southern bay where it joins the main water and runs eastward from the point of entry of the creek. The boundary is indistinct, as in most other parts of this region, since the conglomerate has been greatly metamorphosed; and the acid edge of the eruptive is squeezed into gray green schist much like some parts of the schistose matrix of the conglomerate. From Emma lake to Moore lake the contact lies in swampy ground a little south of the creek, and then crosses the southeast corner of the latter lake toward the western bay of Whitewater lake, the rocks and their relationships being similar to those already described.

Whitewater lake, which is two miles long and in places a mile broad, hides the boundary between the eruptive and the sedimentary rocks for the whole distance, and

Roast heaps, Copper Cliff.

a broad low plain of clay on its northeast side prevents its demarcation with certainty in that direction for a mile to the north. The north shore and the islands which fringe it consist either of the basal conglomerate in a very schistose form, or in the deeper bays of tuff; while the south and east shores are of the acid phase of the nickel-bearing eruptive. Toward the west end of Whitewater lake both shores rise as steep hills to the height of 100 feet or more, unlike the low country along Levy creek, and beyond the hills of tuff to the north there is farming country.

On the north shore of the lake toward the west end a band of gray quartz porphyry cuts the tuff and might easily be mistaken for the acid phase of the nickel-eruptive but for its cutting rocks some distance north of the basal conglomerate. It may be a dike from the acid edge, though the lake prevents one from following it in that direction so as to make certain, and no other dike-like projections are known to extend so far from the edge as this.

The Trout lake conglomerate on the islands and peninsulas of the north side of Whitewater lake is usually schistose, and all the softer boulders and pebbles are greatly flattened, resembling the Michipicoten conglomerates of the Huronian. The strike of the schistosity varies from 45° or 50° to 70°. and the cleavage dips about 45° to the southeast. The boulders enclosed in the conglomerate are of considerable variety, including granite, quartzite, a brownish sandy looking rock, green schist and actinolite, the granite being the commonest rock and forming large boulders not much deformed. The matrix, which is sometimes almost free from pebbles, is gray or green schist merging into a rock like gneiss.

West Smelter, Copper Cliff.

Bays on the north shore give all transitions from the schist conglomerate to a much less altered rock which probably should be classed with the Onaping tuff, though often half the materials of which it is composed are ordinary sediments, including pebbles of the same rocks as in the coarse conglomerate. About a quarter of a mile north of the shore a ridge of characteristic tuff composed mainly of angular volcanic materials represents the completion of the transition.

Toward the northeast end of the lake there are hills of gray gneissoid rock, evidently belonging to the acid edge, and similar rocks are found a mile to the north on the railway west of Azilda station, though the intervening ground is clay; so that the contact changes its direction from N. 65° to nearly due north somewhere beneath the lake. The hill rising from the flat plain of clay west of the station consists of a very schistose rock which has hitherto been mapped as Huronian, but our detailed study makes it practically certain that it belongs to the nickel eruptive, since it has the micropegmatitic structure, and to the north is in continuity with less changed portions of the acid edge.

On the west side of the hill schist conglomerate occurs having a schistose strike of N. 15° and an apparent dip of 15° to the east; but at points to the north and northeast on neighboring hills the strike varies to N. 25° or 30° and begins to bend

eastward once more. Along the road running north from the east end of Azilda a schistose variety of the acid eruptive continues for about a mile, after which the tuff crops out beyond a drift-covered surface.

Copper Cliff Offset

After running for a mile northeast from the Tam O'Shanter, the basic edge of the nickel eruptive turns nearly north for a quarter of a mile and then northeast toward the northern end of the line between lots 3 and 4, con. IV of Snider township It then turns sharply southeast toward the Lady Violet and other mines leading towards the Copper Cliff offset. The northward bend of the contact points toward the southeast bay of Whitewater lake where the acid edge has just been shown to change its direction, so that at this point the nickel range is only about $2\frac{1}{4}$ miles wide, the least width found along the southern range, except near Whitson lake some miles to the east; but immediately beyond this narrowing the range widens once more to almost its maximum.

Along this northward bend there are few traces of ore or even of rusty norite. The rock is coarse-textured but grows finer grained toward the edge, where it is a good deal mixed with the country rock, coarse porphyritic granite, often gneissoid in structure. That the norite is the later rock is shown by its having carried off fragments of granite. The granitoid gneiss forms a group of steep hills in the re-entrant angle of the basic edge, but at the very edge the norite occasionally forms the top of a hill with the gneiss or granite dipping under it. The relations are well shown on a small lake just south of the Manitoulin and North Shore railway between lots 2 and 3, con. IV, of Snider. From this pond the basic edge runs southeast to Clara Bell lake, forming the margin of the upper end of the Copper Cliff offset.

The basic edge to the east of the offset runs from Elsie mine, which will be mentioned later, southwest near the edge of Pump lake to Lady Violet mine, about half a mile north of Clara Bell lake on the line between lots 1 and 2. At the Lady Violet mine the boundary swerves nearly west for about one-fifth of a mile, and then turns south and finally southeast, parallel to the basic edge referred to above. The offset in its upper portion, northwest of Clara Bell lake, is from 500 to 600 feet broad; and represents the outlet of a bay of norite almost as wide and deep as that of Creighton mine, though more regularly shaped.

The norite of central parts of the offset is like the main body of the rock, but along the edge toward Clara Bell lake where it comes into vertical contact with rather coarse granite, it becomes finer grained and occasionally picks up fragments of the adjoining rock, and may also contain pebble-like fragments or plates of a very fine-grained older norite. The southwestern margin of the offset shows few traces of ore but the northeastern side is commonly rusty and at the Lady Violet and Clara Bell mines enclosed small bodies of ore which were worked for a time in the early days of the Canadian Copper Company. The Lady Violet shows rather coarse norite with an irregular rusty edge against greenstone, and conditions are similar at the Clara Bell, where a gossan-covered hill consisting mainly of greenstone marks the boundary. On the dump at the latter mine, which is now dismantled, one finds beside norite, chlorite and hornblende schists and a number of minerals in addition to the usual pyrrhotite and chalcopyrite, such as quartz, calcite, dolomite, and actinolite in blades several inches long, indicating secondary water action. During mining operations a pocket of about five tons of magnetite was found completely enclosed in the sulphides.

After reaching Clara Bell lake the offset expands to a width of nearly half a mile with a projection to the northeast and another to the east. The rocks to the west and south are porphyritic granitoid gneiss, formerly considered to be Laurentian, while on the northeast various greenstones, diorite, hornblende porphyrite, hornblende schist etc., rise as hills, the norite occupying in the main lower ground between the greenstone

and the gneiss. The norite is somewhat patchy, containing finer-grained parts, often angular, and sometimes also fragments of greentsone or green schist. Clara Bell lake has been dammed at its outlet and now covers much of the low ground, hiding the norite contact at some points.

On the eastern edge of the northern tongue an ore deposit of considerable magnitude was opened up years ago at No. 4 mine and the great open pits partly filled with water suggest a large but very irregular segregation of the sulphides.

At the eastern corner the projection of norite touches Lady Macdonald lake, and close to the shore is Lady Macdonald, or No. 5, mine, the first of the series of mines to be worked, now closed down like the others. An open pit near the lake is at the margin of the norite against mixed greenstones and not far from the granitoid gneiss, which is greatly mixed with it as a crush breccia. On the dump there are pegmatite, hornblende schist, hornblende porphyrite and a little re-crystallized arkose, as well as norite. A few scales of graphite were found in one mass of gneissoid rock. It is probable that a dike of pegmatite cuts the norite and ore at this mine, but the exposure is too poor to make this quite certain.

No. 2 Mine

Lady Macdonald lake, like Clara Bell, has been dammed to afford a water supply, and cuts off the broad expansion of norite containing the mines just mentioned from a narrow extension southeast to No. 2 mine. An island in the northern part of the lake consists mainly of granite but at its eastern end shows a gossan-covered patch of norite, and at the end of a bay on the east shore of the lake a band of norite from 100 to 180 feet wide runs for about one-third of a mile and is then lost to sight beneath a clay deposit. About 350 feet farther to the southeast there rises the small strip of norite in which the mine is sunk.

The norite band just outlined is of finer grain than the main range and is spotted with little rusty cavities from which ore has been weathered where it not quite covered with gossan. It begins between granitoid gneiss, to the southwest, and a greenstone hill including long strips and masses of well stratified graywacké to the northeast, but presently passes entirely into the gneiss. The southeast end near the mine is once more between greenstone and granite; and it appears that the contact between the two rocks was a line of weakness, probably also of faulting, permitting the molten norite and ore to flow in this direction. The granitoid gneiss is younger than the greenstone, enclosing bits of it, and both rocks are cut by minor fault lines and often squeezed into breccias. In the gneiss the breccia blocks are variously oriented and cemented by similar materials crushed fine.

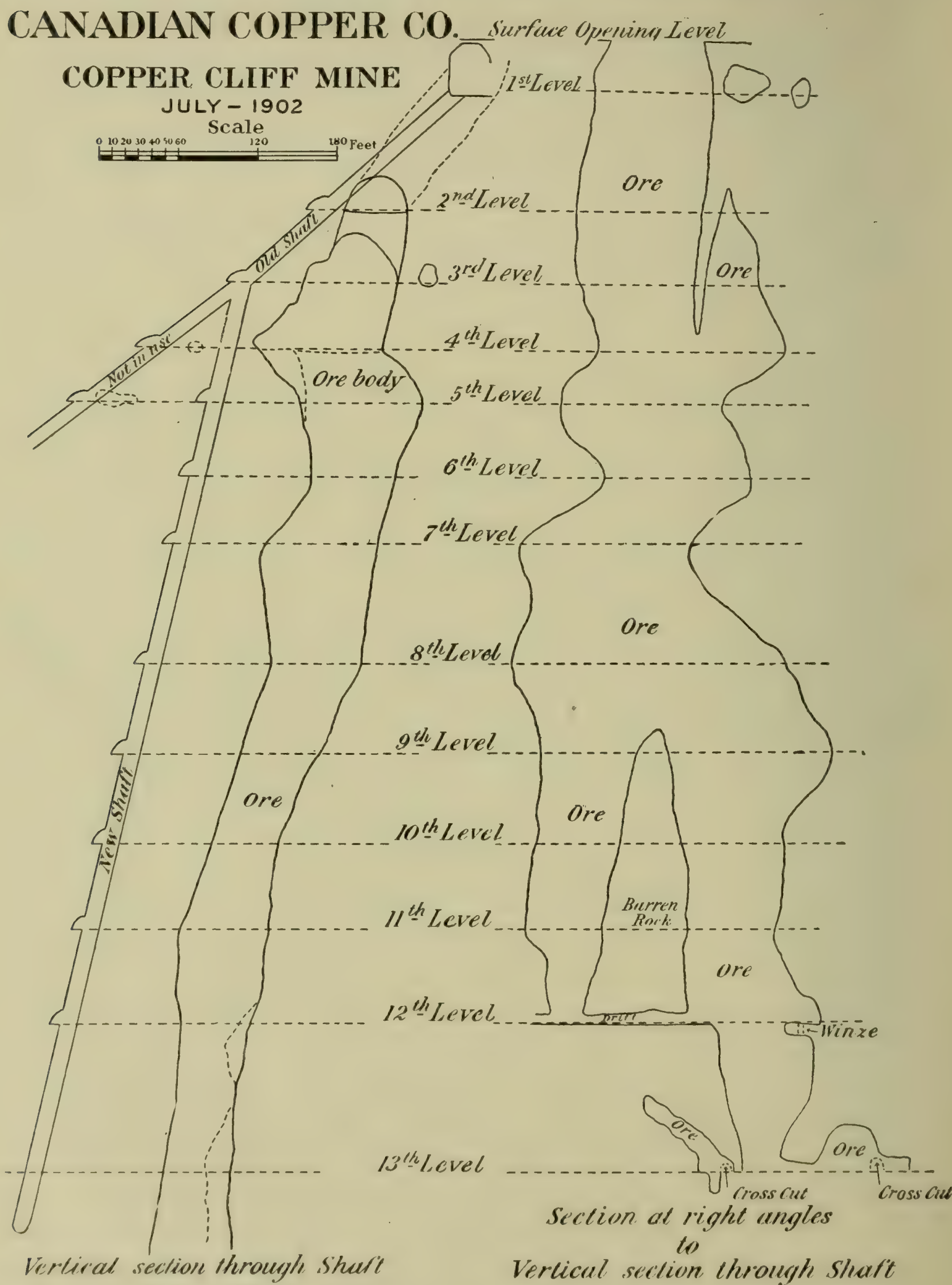
The dike-like band of norite grows finer grained at the edges, and is evidently later than the two rocks mentioned, but a dike 8 or 10 feet wide of non-porphyritic, rather fine-grained, granite, quite different from the gneiss, runs through it for some distance.

All along this norite offset there is more or less ore which has been opened up by small pits or shafts; but the only important ore body disclosed is No. 2, at the southeast end of the band near the point where it is apparently cut off by the older rocks, the relations being somewhat obscured by drift. The ore was present here in such volume that almost the whole width of the band consisted of sulphides, with an irregular margin of fine-grained norite against the granite walls, and with a large flange of norite projecting into the ore from the western wall.

The great open pit is about 230 feet long from northwest to southeast and half as wide, and it has a depth of 278 feet, while lower levels and diamond drill cores prove that it continues to a depth of at least 402 feet. The irregular column of ore stands not far from vertical, but inclines slightly to the west, and at the third level or pit floor it has diameters of 220 feet from north to south and 100 feet from east to west.

The Copper Cliff Mine

A valley filled with sand and clay extends for a third of a mile to the south of No. 2 with no indication of a continuation of the offset except a little outcrop of norite near a stream crossing the main street of the town. A short distance south of this



and quite to the westward of the normal continuation of the offset rises the gossan hill of the famous Copper Cliff, next to the Creighton the most important mine of the

region and containing still richer ore. This was one of the earliest mines worked, having been located for its copper ore before its value as a nickel mine was known.

The rusty norite hill is surrounded on three sides by stratified clay, but toward the east lies against graywacké and flesh-colored arkose, the latter largely re-crystallized and formerly regarded as felsite or syenite. The arkose is cut by two granite dikes, one at the edge of the norite, and the latter rock is cut by two small dikes of diabase. The rusty hill is nearly 600 feet long and 200 wide.

The large rock dump at the mine contains a variety of materials, the most common being rather fine-grained norite with a little quartz, commonly called diorite, but there seem to be all gradations from this to a pale gray diorite merging into red granite. The norite has coarse varieties with some biotite and also hornblende crystals, and sometimes pegmatitic parts with large gray feldspar crystals, generally striated, almost to the exclusion of other minerals . There are also felsitic looking rocks, gray to red, arkoses as shown by thin scetions. Finally there are numerous blocks of diabase, evidently from dikes, occasionally the whole width being shown in the blocks, the margin being finer-grained than the centre. The diabase is not porphyritic as at the Creighton mine. The norite mentioned may be found more or less charged with sulphides, and there are brecciated masses of rock cemented with sulphides. Among minerals, in addition to those belonging to the ore and rocks, there are calcite, quartz, and small amounts of galena.

A dike of diabase is said to have been followed down from the third level to the thirteenth, part of the dike matter containing ore, and having a margin of calcite on one side and of quartz with some ore on the other. The largest dike encountered is said to be very fine-grained and black, and to be twenty-five feet wide. Cores from diamond drill holes below the thirteenth level show, in addition to ore and the usual rocks, diabase dikes and a dike of medium-grained biotite granite.

As shown by the sections given, prepared from the plans of the levels in the mine with aid from Captain Lawson, who has charge of the underground workings, the ore body is roughly cylindrical, narrowing and widening several times and broken by a large horse of barren rock, beginning between the ninth and tenth levels. Many thanks are due to the mine authorities, and especially to Captain Lawson, for this instructive section of the deepest mine in Ontario, a mine that has reached a depth of 937 feet.

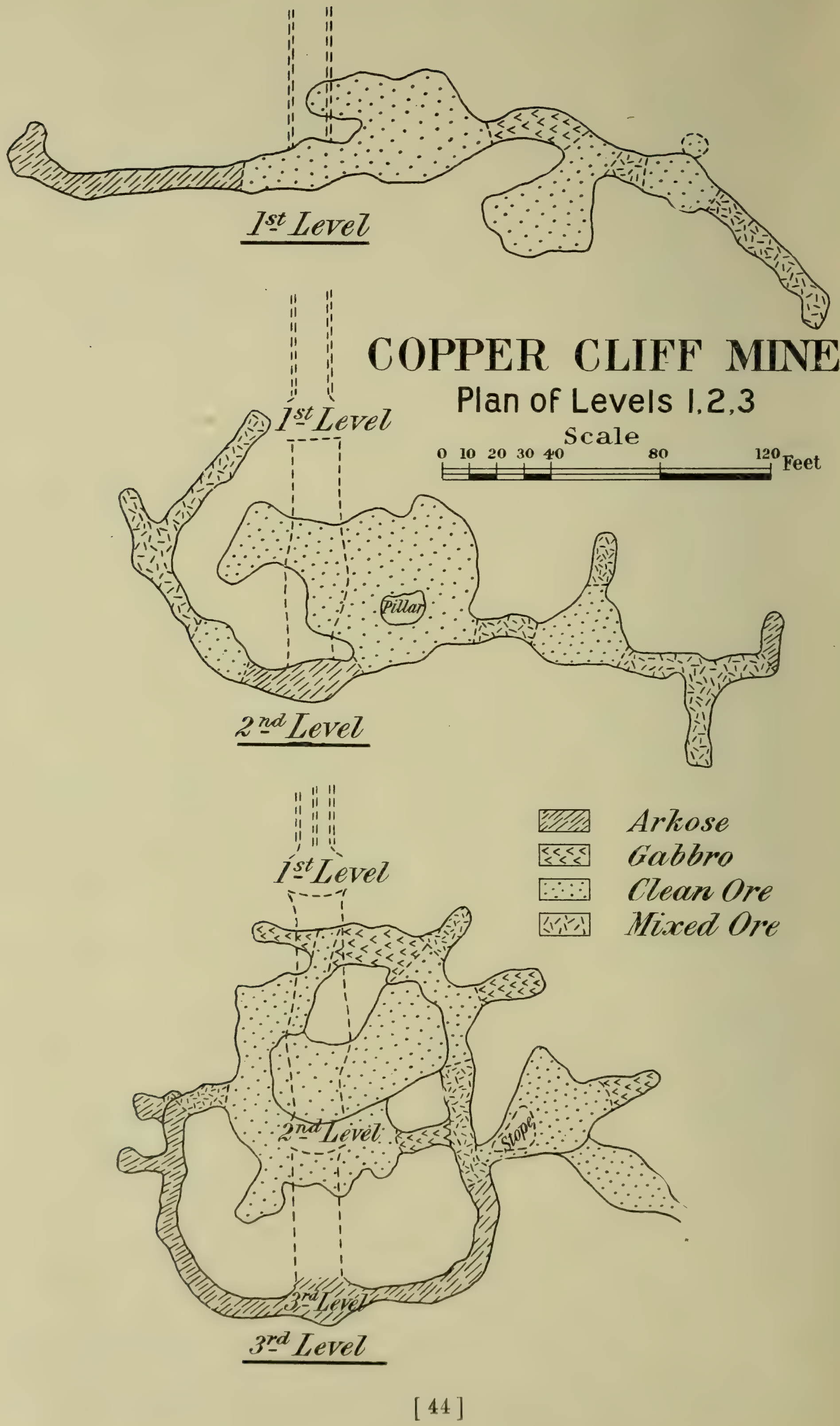
One curious feature of the later development of the mine is the finding of an odorless gas which may be lit with a candle in drill holes through ore at the thirteenth level.

The chimney-like ore body has a width of from 50 to 90 feet in the section through the shaft, which is inclined about 77½° toward the northeast, and from 75 to more than 200 feet in the section at right angles to it.

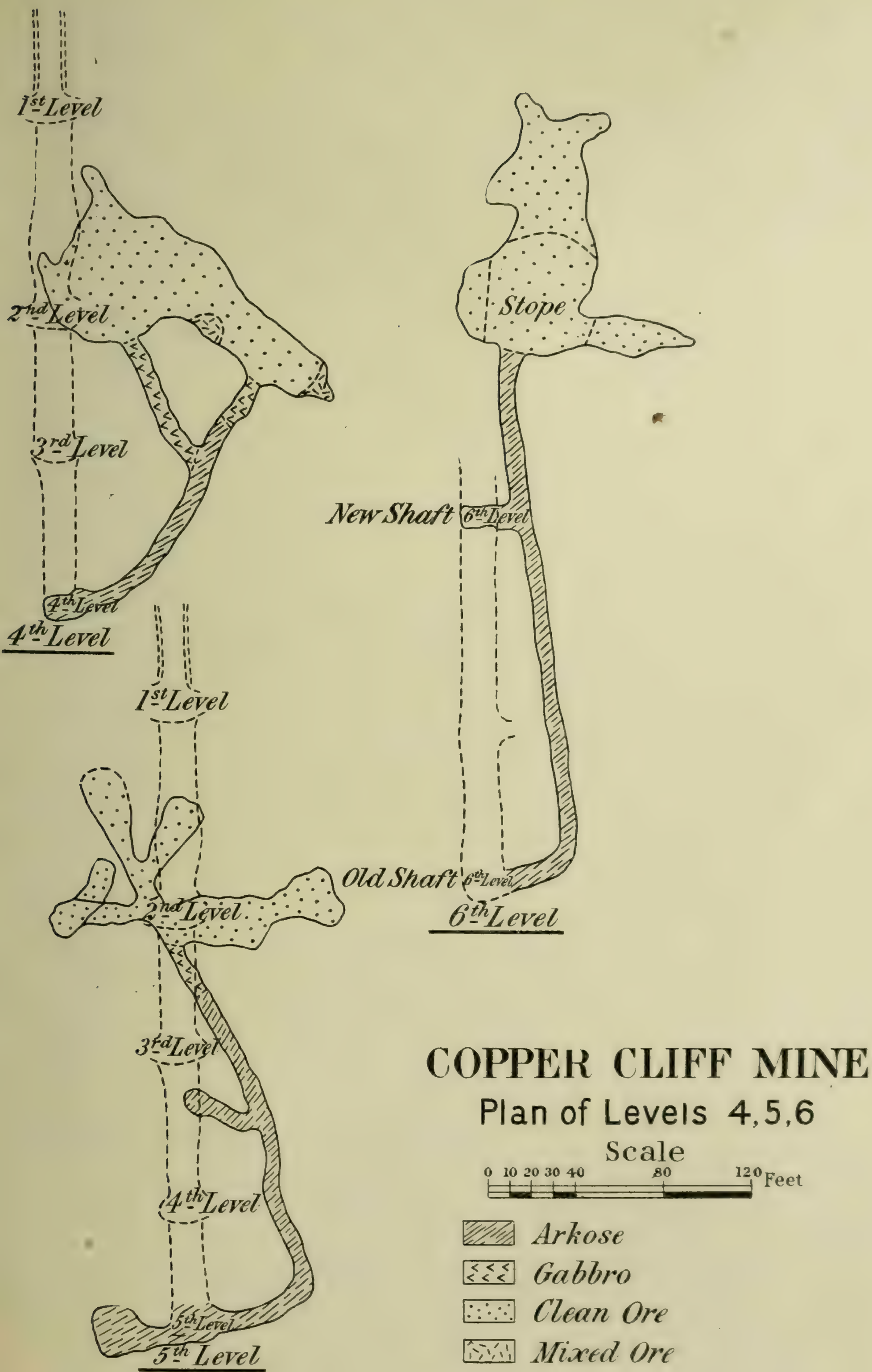
In the Copper Cliff, as in No. 2, the amount of ore seems greatly disproportionate to the size of the band of norite with which it is connected, and a certain quantity of the ore, being associated with quartz and calcite, must be of later deposition than the ore enclosed in the norite. The fact that two slips are rather marked features at the mine may indicate fractures and fissures in which water currents could circulate, and deposit there materials dissolved out of previous ore masses belonging to the original consolidation after the norite reached its present position.

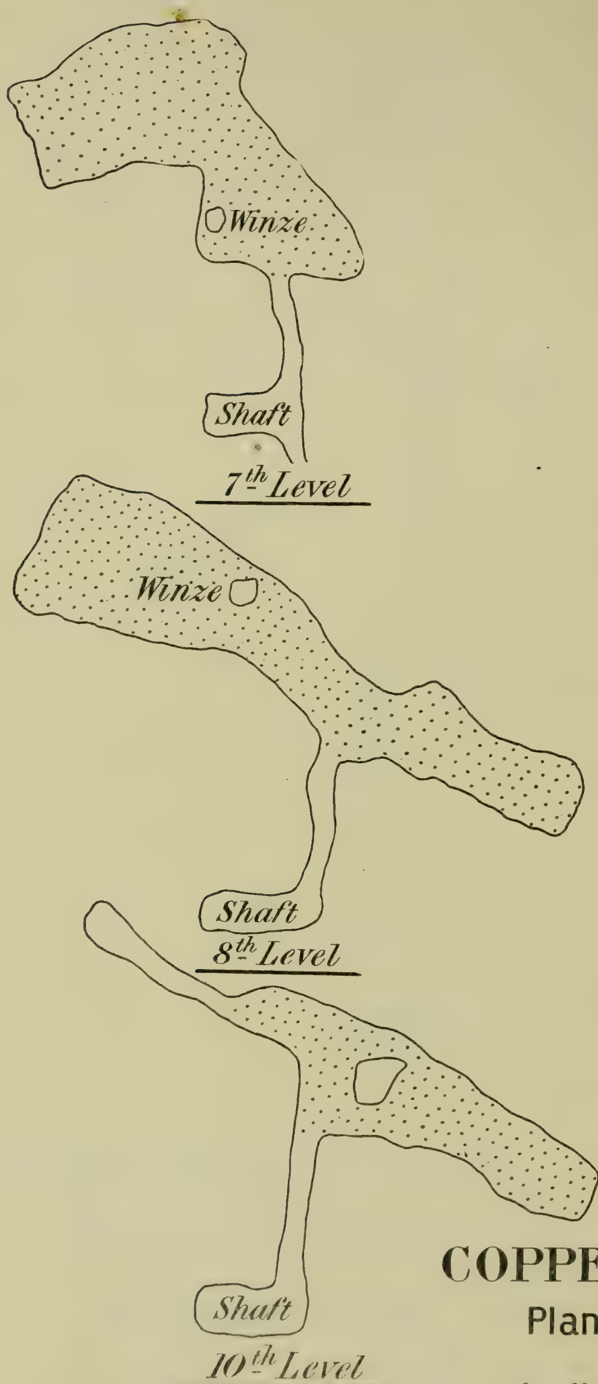
It is stated that when the ore body in the Copper Cliff is narrow it is richer in copper, and when it widens it becomes richer in nickel.

About 700 yards southwest of the Copper Cliff a small band of gossan-covered norite rises cut of a swamp and runs southward towards the old Orford refinery. The norite associated with the ore has the customary pitted surface where spots of pyrrhotite have weathered out, and runs with interruptions beween well-stratified graywacké



COPPER CLIFF MINE
Plan of Levels 1,2,3
Scale
0 10 20 30 40 80 120 Feet
Arkose
Gabbro
Clean Ore
Mixed Ore
1st Level
1st Level
Pillar
2nd Level
1st Level
2nd Level
Stope
3rd Level
3rd Level


1st Level
2nd Level
3rd Level
4th Level
4th Level
1st Level
2nd Level
Old Shaft
6th Level
3rd Level
4th Level
5th Level
5th Level
Stope
New Shaft
6th Level
6th Level
COPPER CLIFF MINE
Plan of Levels 4,5,6
Scale
0 10 20 30 40 80 120 Feet
Arkose
Gabbro
Clean Ore
Mixed Ore



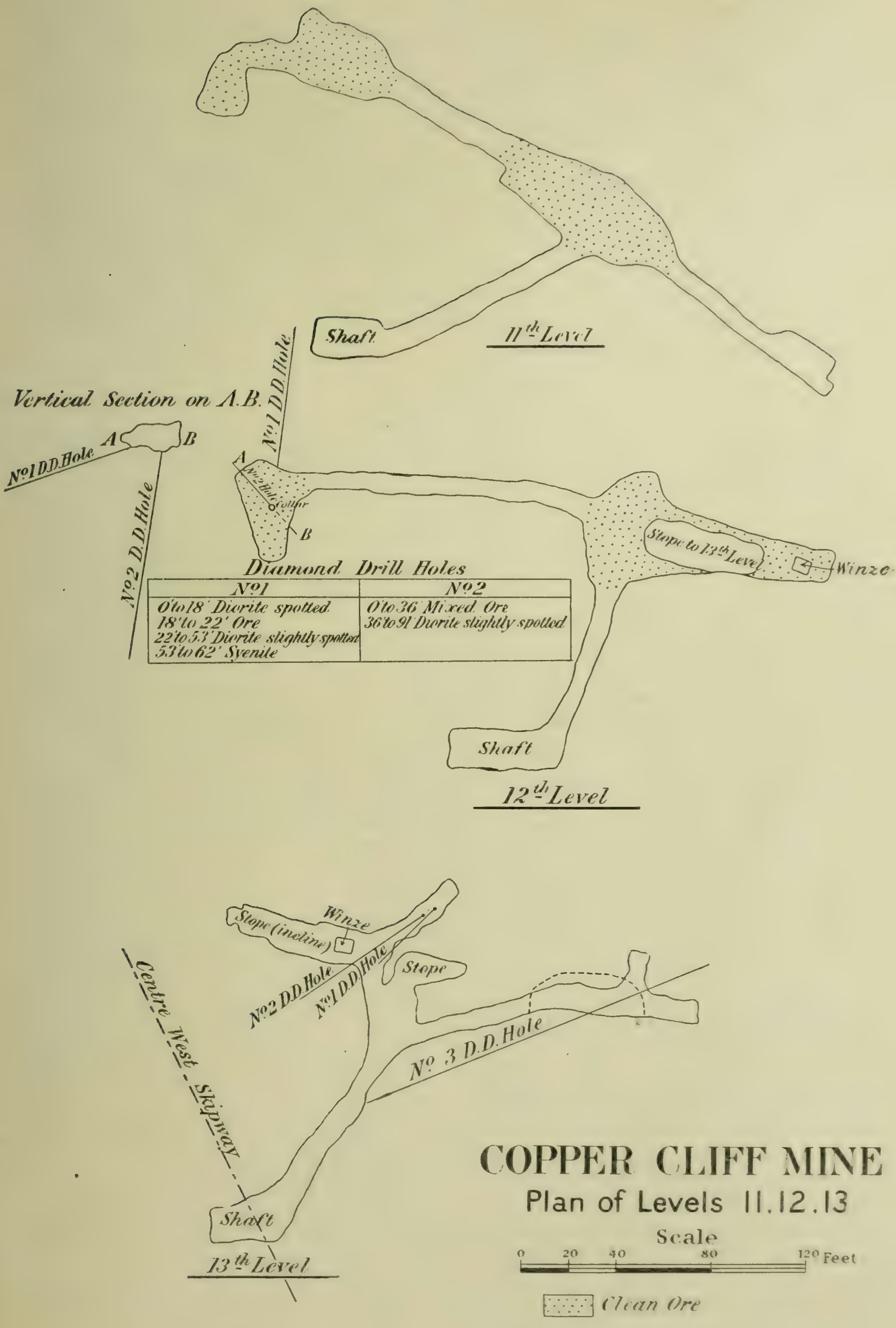
COPPER CLIFF MINE

Plan of Levels 7, 8, 10

Scale

0 20 40 80 120 Feet

Clean Ore



Diamond Drill Holes

No 1	No 2
0' to 18' Diorite spotted 18' to 22' Ore 22' to 53' Diorite slightly spotted 53' to 62' Syenite	0' to 36' Mixed Ore 36' to 91' Diorite slightly spotted

COPPER CLIFF MINE
Plan of Levels 11.12.13

and a steep hill of pink felsitic looking arkose. Several pits have been opened upon the band, including No. 1, near the water tank of the refinery, from which some thousands of tons of rich ore were taken, but all are now filled with water so that not much more than the surface can be seen. The amount of norite as compared with ore seems to be reduced to a minimum, or even to vanish altogether in a confused intermingling of blocks of graywacké with thin seams of the eruptive.

At the most southerly large open pit hornblende porphyrite shows itself in considerable amounts, and the true norite or gabbro can scarcely be discovered at all It is as though almost only ore, out of the original mixture of ore and norite, had been forced into this narrow fissure. At the widest the band scarcely goes beyond 50 feet, and in the long extension toward the former Orford club house it narrows down to eight or ten feet. Several dikes of diabase cut the hill of arkose and approach the open pits, one or two of them actually crossing the norite band, but it is doubtful whether they have had any effect on the ore bodies.

The Evans Mine

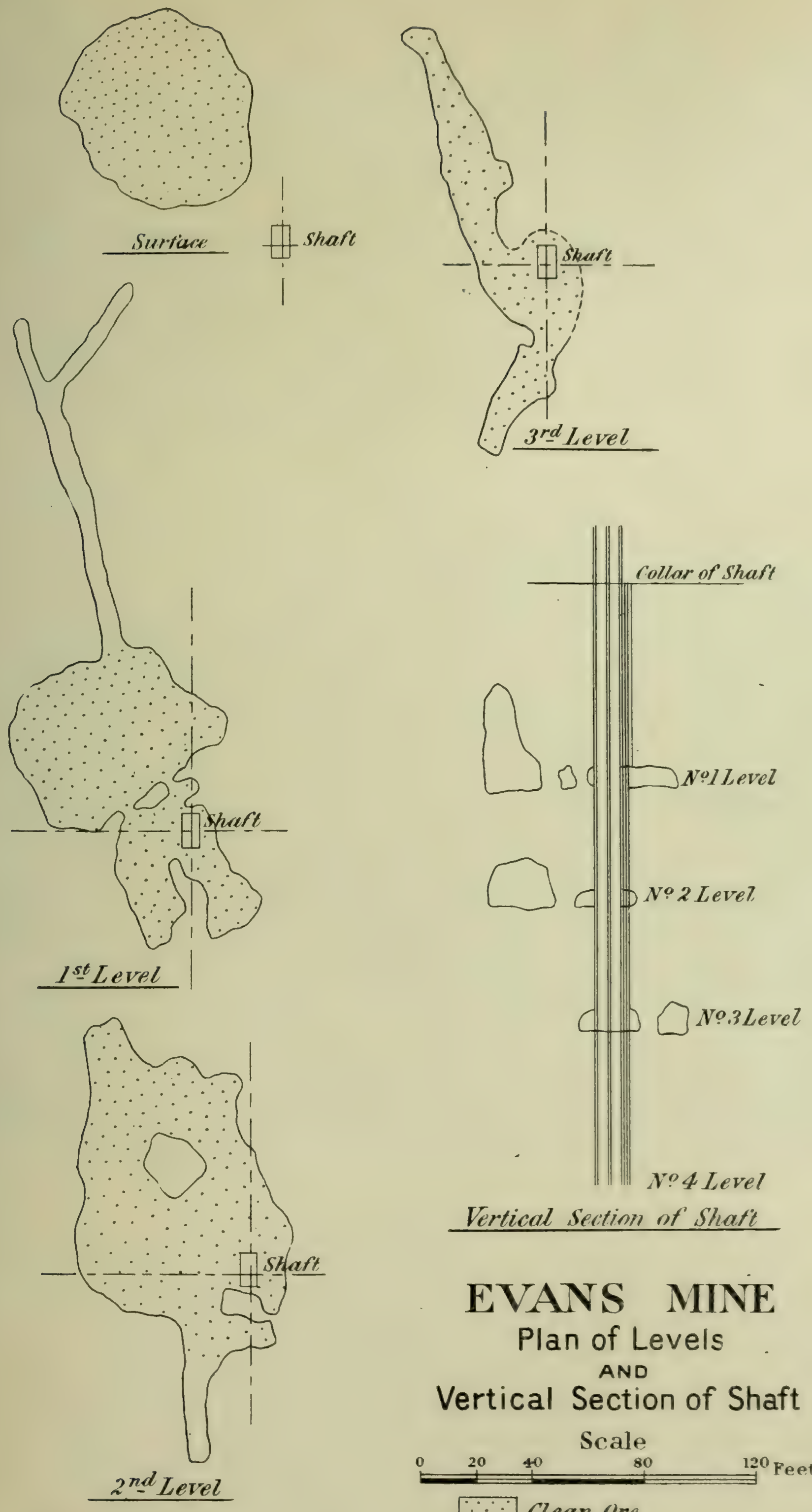
After an interval of about two-thirds of a mile of swamp and clay flats with no solid rock but a few low mounds of graywacké, the small gossan hill of the Evans mine rises gently above the clay, but is now mainly covered by the rock house and rock dumps, except at the two open pits filled with water. There is little to be learned at present from the surface outcrops, though the large rock dump shows a considerable variety of types, including gabbro, diabase (probably from dikes), graywacké and various products of weathering, such as actinolite rock. Much slickensiding was noticed on the blocks of rock.

The mine was worked by open pits to a depth of about 160 feet, and below this by levels to the depth in all of about 250 feet.

The question as to whether the Evans outcrop should be connected with the narrow band of ore-bearing gabbro two-thirds of a mile to the north near the Orford refinery, or with the ridge of gabbro rising only 400 yards to the southwest near Kelly lake is one of considerable interest and should be briefly discussed. The connection with the nearer gabbro area seems at first the more natural, but there are reasons for deciding in favor of the other theory. In the first place, all the important ore deposits in the Copper Cliff region are on what may be considered one curved belt of norite projecting from the main range and everywhere gossan-covered, indicating the presence of sulphides. On the other hand, the band of gabbro to the southeast of the Evans mine differs in character from the typical nickel-bearing norite. It resists weathering and rises as sharp ridges of hills, while the nickel-bearing norite generally has only low relief; it is never gossan-covered at its junction with other rocks, and only very small deposits of nickel ore have been found in it, and then only at a considerable distance from the margin.* The gabbro belt near Kelly lake is narrow, averaging only about half a mile in width, but it connects about six miles to the northeast with a larger mass several square miles in area, just east of Sudbury. The narrow band and the main body rise through the sedimentary rocks in what seems a laccolithic way, tilting the slaty graywackés up on their flanks till they are nearly vertical or even slightly turned the other way; and this turned-up edge of graywacké runs right on between the gabbro ridge and the Evans mine as if quite undisturbed.

Still another point has a bearing on the question. The main range uniformly blends to the northwest into micropegmatite and granite, while the Sudbury gabbro mass with its prolongation to the southwest has no such peculiarity. The Kelly lake band of gabbro, then, is of quite different characters from the usual nickel-bearing norite, and having no ore bodies itself would be unlikely to send off from its flank such a large mass of ore as the Evans mine.

If the Evans ore body is connected with the band to the north, why should there be a gap of two-thirds of a mile between it and the next outcrop? This is not easy


Surface
Shaft
3rd Level
Shaft
1st Level
Shaft
2nd Level
Shaft
Collar of Shaft
No 1 Level
No 2 Level
No 3 Level
No 4 Level
Vertical Section of Shaft
EVANS MINE
Plan of Levels
AND
Vertical Section of Shaft
Scale
0 20 40 80 120 Feet
Clean Ore

to answer, but one may suggest that connecting links are buried under the clay flats between; or the explanation current among prospectors may be accepted, that there is a subterranean connection between the outcrops "capped over" at certain points. If the latter is the case and the ore-bearing connection is not at too great a depth there should be magnetic disturbances between two outcrops, but this has not yet been demonstrated.

The evidence points toward a real connection of these chimneys of nickel ore among themselves by tortuous channels which have not always reached the surface, the chimneys representing weak points in the overlying rock where the more fluid part of the mixture of rock and ore, which would of course be the sulphides, could be forced upwards, sometimes as a column more than a thousand feet in height, as at the Copper Cliff. It is possible, however, that the connecting channel lay *above* the present level and that the heavier ore descended where opportunity offered. Since then the upper canal may have been removed, along with the thousands of feet of rock which have undoubtedly been planed off since Archean times.

The Copper Cliff offset, though only about three and a quarter miles long, and therefore shorter than two other offsets, at Worthington and in Foy township, is much the most important in the Sudbury region, for its ore deposits have already supplied more than 800,000 tons of rich ore.

The peculiar arrangement of the nickel range between this offset and that at Worthington, as if a block of the Archean support 11 miles long on the acid side and 16 miles long on the basic side had slipped down, producing faults at each end through which an outlet was afforded to the molten rock and sulphides, has already been mentioned; and the greater irregularity of the Copper Cliff offset is perhaps due to the variety of the rocks forming the substratum. This offset differs from the other two in the much greater volume of sulphides distributed along it and in its greater discontinuity, the southern outcrops, at Copper Cliff, the former Orford smelter, and Evans mine, being separated from the main offset and from one another by spaces of from a quarter to three-quarters of a mile.

There seems to be a connection between halts or obstructions in the devious channel followed by the molten material and the accumulation of sulphides, the main ore deposits occurring at the end of a continuous band of norite as in No. 2, or in isolated outcrops, as at the Copper- Cliff and Evans mines. Dr. Peters' comparison of these ore bodies to a string of sausages with a long bit of string between the sausages is very apt.

As the line of outcrop in the isolated parts does not correspond to the original southeasterly direction of the offset it is possible that faulting has taken place since the consolidation of the pyrrhotite-norite magma, producing the discontinuity and causing horizontal displacement toward the west, but in the large amount of minor faulting it has not yet been proved that there are main faults of this magnitude.

Elsie Mine

Returning to the basic edge of the main range the contact can be followed northeast from Lady Violet mine, passing to the southeast of Pump lake and then turning east towards Elsie mine. The norite is of the usual kind and most of the way is in contact with granite, partly coarsely gneissoid, having a strike of 65°, and looking like Laurentian, but partly medium-grained, flesh-colored, and probably later than the norite. With the granitic rocks are occasional hills of "older norite" and of greenstone near the boundary between Snider and McKim townships; and at the Elsie mine, in lot 12, con. V of the latter township, various greenstones cover a large area to the south of the contact.

Elsie mine is situated at a small embayment of the norite, which lies as a low plain extending for a mile or more to the north with little change of level. The

norite is weathering rapidly into rounded boulder-like masses partly buried in the coarse sandy materials resulting from the decay of enclosing rock, giving clear evidence of the origin of the plain.

At its edge the norite shows rusty, pitted surfaces as usual, and these increase till the elongated ore body is reached, where an open pit shows that the foot wall of various greenstones slopes at an angle of about 29° to the northwest. The clean ore has a thickness of 20 feet, but is in irregular pockets, while above it there is mixed ore and norite, in some places for about 40 feet. There has been some slipping and slickensiding, but the surface of the underlying rock is much more uniform than at other mines, such as the Creighton.

The ore, which is less rich than in the mines to the southwest, is almost wholly pyrrhotite and chalcopyrite, though a few seams of quartz and calcite with clay and iron pyrites occur. The pyrites contains no nickel.

Jointage of greenstone south of Elsie mine.

To the west and north of the mine the coarse-textured norite with the usual blebs of bluish quartz and black mica occasionally varies into patches of a much coarser grained variety with a suggestion of concretionary structure, consisting of vague bands which contain more hornblende toward the outer edge and more plagioclase toward the centre, with which there is usually a considerable amount of quartz intermixed. These areas vary from the size of one's hand to several square yards, and seem as a whole to be distinctly more acid than the average norite.

The Elsie mine dump shows a considerable variety of rock beside the norite, quartzite or felsitic arkose and greenstones being the commonest; and the hill which rises steeply to the south presents an even greater variety. At the foot near the ore there are some bands of arkose or quartzitic rock, evidently sedimentary, mixed with hornblende porphyrites, but higher up the hill the prevalent rock is "older norite,"

fine-grained and gray in color with a network of slightly raised green bands on weathered surfaces. Thin sections prove that this rock consists of plagioclase and hypersthene without quartz, sc that it is a more basic rock than the nickel-bearing norite.

The older norite is mixed with or passes into, several other rocks, especially greenstones and hornblende porphyrites, but also an amygdaloidal rock showing very pronounced "pillow structure," indicating surface lava flows. The pillows may be from a few inches to four or five feet in diameter, and consists of a paler centre, sometimes older norite, with a dark margin having two or three inches of the outside thickly sprinkled with small white amygdules.

A wide band of this mixture of greenstones extends south toward Copper Cliff, covering several square miles.

Murray Mine

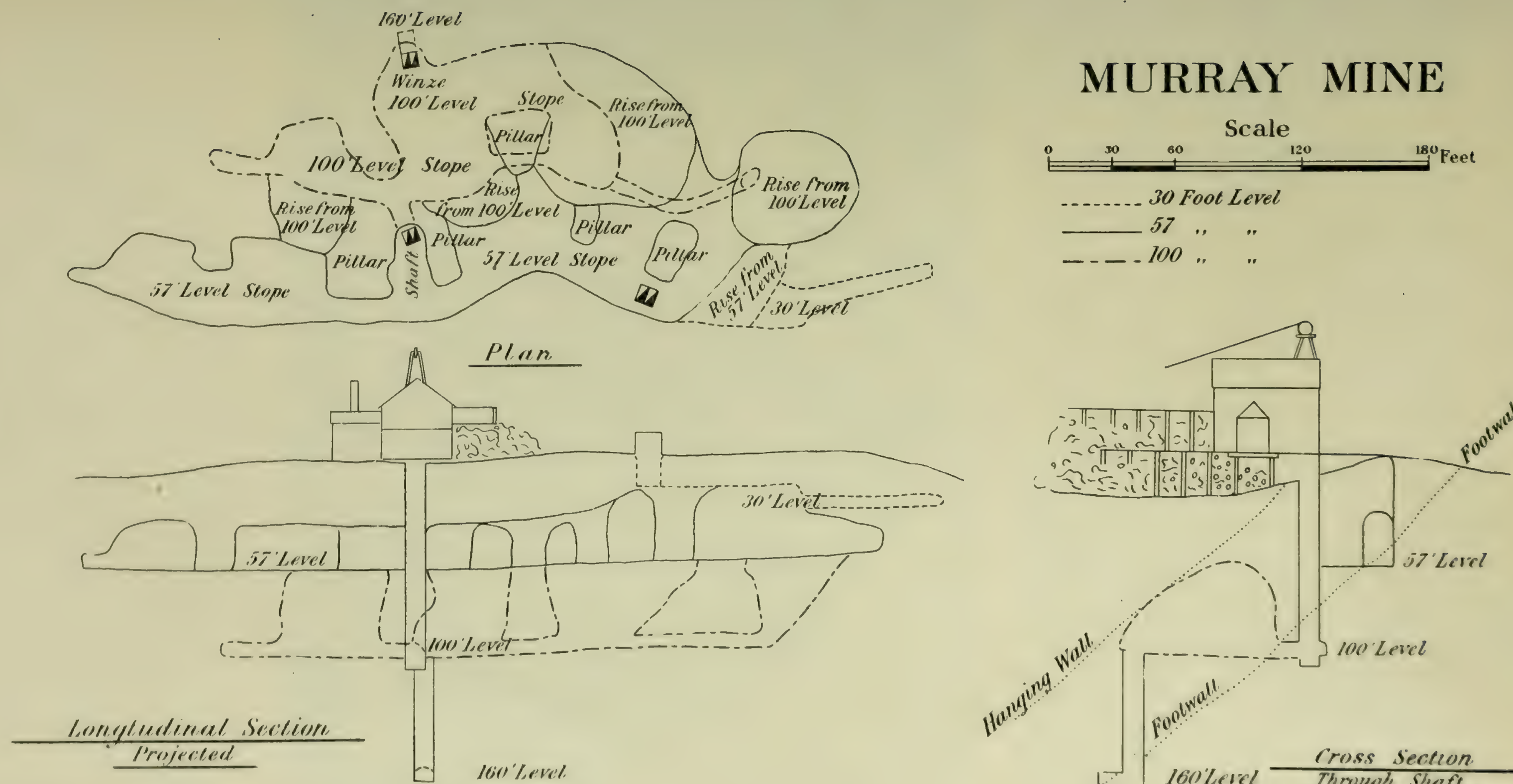
The gossan edge of the norite at Elsie continues without a break toward the northeast to Murray mine on the north half of lot 11. This is one of the oldest and most carefully studied of the mines of the region, Baron von Foullon and Professor T. L. Walker having worked upon it, proving that the accompanying rock, up to that time called diorite, was really norite. For a number of years, however, the mine has not been operated, and conditions are not now favorable for its examination.

Much of what has been said of the Elsie mine applies to the Murray mine also; but the band of gossan is wider here and apparently the ore body considerably larger. Several large dikes of olivine diabase cross the norite, some of them cutting the ore body itself, and run in the direction 125° towards Ramsey lake near Sudbury, their course having been determined by Dr. Barlow. As the conditions of the mine are not easily seen at present it may be well to quote a description of it from one of the gentlemen who operated it 12 years ago.

In 1893 Captain Richards stated to the Inspector of Mines that "the ore body, which possesses an average thickness of 70 feet, strikes in the direction northeast and southwest and dips northwesterly 45° from the horizontal. This agglomerated mass of nickeliferous pyrrhotite and diorite is contained by diorite walls. The foot wall at certain points, as proved by mining operations, presents the appearance of a true fissured plane upon which, at some time or other, the ore body has moved, as evidenced by the coarse flucan or attrited matter which separates the ore from the wall. In some places through the occurrence there exist large inclusions, horses or intrusions of diorite containing fragments of granite." As these mines are now full of water, little can be said of the relationships of the ore body to the adjoining rocks beyond what is visible on the surface. The character of the norite mass has been elaborately described by Dr. T. L. Walker, so that it is only necessary to say that it is the ordinary coarse-grained rock with bluish quartz. The contact of the norite with the adjoining rock runs about northeast from the Elsie to the Murray mine, and continues in the same direction past the latter, more or less gossan marking the boundary all the way. The hornblende schist and porphyrite forming the foot wall at the Elsie is largely interrupted at the Murray mine by dikes from the southeast end of an area of red granite later in age than the norite, which it has penetrated in the most confused way, sometimes forming a giant breccia of norite blocks with narrow seams of granite between, but part of the apparent granite may prove to be squeezed and modified arkose or re-composed granite. The greenstone near the Murray mine is sometimes sheared into schist with bands of lighter and darker green, showing great dynamic action.

On the dump of the Murray mine much of the norite is found to be filled with sulphide granules of all sizes and in all proportions, as at most other nickel mines, the ore being in coarse grains when the rock is coarse and *vice versa*. In addition to the

MURRAY MINE


Scale
0 30 60 120 180 Feet
30 Foot Level
57 " "
100 " "
160' Level
Winze
100' Level
Stope
Rise from 100' Level
Pillar
100' Level Stope
Rise from 100' Level
Rise from 100' Level
Rise from 100' Level
Pillar
Pillar
Shaft
Pillar
57' Level Stope
Pillar
57' Level Stope
Rise from 57' Level
30' Level
Plan
30' Level
57' Level
100' Level
160' Level
Longitudinal Section
Projected
Footwall
57' Level
100' Level
Hanging Wall
Footwall
160' Level
Cross Section
Through Shaft

usual country rocks on the dump there is a very coarse "malchite" consisting of green hornblende blades sometimes six inches long and white plagioclase with more or less quartz, evidently a segregation of the sort found at Elsie, but of a much coarser texture.

To the northeast of the mine the gossan-covered edge of the norite extends for half a mile with a few small outcrops of ore exposed by stripping or test pits from point to point. In one place a large dike of diabase has been partly stripped as if in searching for ore, just to the east of a mass of gossan. Superficially the two rocks are somewhat alike, though the diabase shows no quartz blebs, and is not pitted with gossan spots. At these outcrops the gossan leans against the older rock as at Sultana mine.

The range of later granite hills to the southeast of the Murray mine runs for some miles parallel to the edge of the norite, and in some places encloses patches of greenstone, etc., while it is cut by the diabase dikes mentioned above. One of the largest dikes has weathered out leaving a vertically walled passage 150 feet wide through a ridge of granite a little east of Murray mine, providing an easy grade for the old road from Murray mine to Sudbury.

Jointage of granite west of Murray mine.

Where the Canadian Pacific railway crosses the nickel range between Murray mine and Azilda (formerly Rayside), there is an excellent section displayed, which was described by Prof. Walker years ago,[23] but may be referred to here as one of the best known. The whole width at this point is about four miles, so that this is one of the broadest parts of the range, being surpassed only by the part north of Creighton. Near the mine the norite is of varying texture and largely mixed with ore as pyrrhotite-norite, and except for a somewhat coarse texture there is little variation for a mile and a half to the northwest along the railway or the wagon road to Azilda. At a few

[23] Quar. Jour. Geol. Soc., London, Vol. LIII (1897), pp. 47-54.

points the weathered surface looks somewhat reddish toward the northwest corner of McKim township, but fresh specimens have the usual dark color of norite. Where the road and railway pass from McKim into Snider township and descend towards the Rayside plain rather fine-grained granite crosses as a band about 400 feet wide but very irregular; and half a mile farther northwest there is a similar band. Here the eruptive becomes more acid in character and redder in color, while the rock rises as hills in a pronounced way, probably because of its change in composition, since it no longer weathers rapidly as in the low plain toward the basic edge.

Where road and railway pass into a bay of flat clay land the acid phase of the eruptive has distinctly come in, with flesh red weathered surfaces and very rugged forms with steep slopes or cliffs toward the valley. Beyond this the eruptive is very schistose, resembling gneiss or felsite schist and has been mapped by the Geological Survey as Huronian, though the finding of the basal conglomerate on a hill half a mile northwest of Azilda station, with typical granite boulders and the usual intense metamorphism proves that all the schistose rocks between the hill and the red cliff previously mentioned must be included in the acid phase of the eruptive. This view corresponds with that taken by Prof. Walker.[24]

Blezard Mine Region

From the small outcrops of ore in the southern half of lot 10, con. VI, cf McKim township to the Cameron mine in lot 7, con. I, of Blezard, a distance of about two miles, the basic edge runs with minor curves toward the northeast, showing little gossan or other evidence of ore. The norite along this portion is in contact with later flesh-colored granite.

At the Cameron mine, where a small ore body has been developed, there is a slight bay of the basic edge, which here turns nearly east to the Little Stobie mine near the north end of lot 6. Along this part of the contact the relationships are largely concealed under drift deposits and by woods.

At the Little Stobie an open pit discloses ore resting against green schist and hornblende porphyrite; and the norite shows a little to the north and also to the southwest in a phase suggesting breccia or conglomerate, the usual rather coarse gray rock enclosing crowded fragments of the finer grained older norite.

In lot 8, con. II, of Blezard township, about a mile northwest of the Little Stobie, a small pocket of ore was found by dip needle work by Mr. Edison's party, and a test pit and diamond drill holes were sunk there to explore for ore, but without success. The drill core showed norite, weathered or fresh, to the depth of 1,030 feet, with, however, a band of schist at about 260 feet and a considerable thickness of fine-grained granite at 900 to 950 feet.

On the way to the camp two small outcrops of granite are found, so that here as northwest of Murray mine dikes of granite cut the norite.

From Little Stobie the contact runs northeast to the north corner of lots 5 and 6, con. I, and then east as a small embayment to Mount Nickel mine, which has been partially developed by two open cuts, the sinking of a shaft to a depth of 165 feet, and a considerable amount of drifting at the 75-foot level. This work and two diamond drill holes are said to prove that there is a good body of ore, dipping at about an angle of 30° toward the north, and the ore dump is of respectable size and quality. The open cuts show that the ore is partly to the south of the norite in fractured and broken greenstone, as if it had been squeezed into the fissures while molten, by pressure from the north, thus forming a sort of breccia of rock fragments cemented by pyrrhotite and chalcopyrite.

24 Ibid, p 53

Blezard Mine

From the Mount Nickel mine the contact bends gently toward the northeast to the Blezard mine in lot 4 in the second concession of the township of the same name. Mr. Robert McBride, who was captain of the mine in 1892, states that it was opened in 1889 and 1890 by the Dominion Mineral Company, and shut down in 1892. At present the surface is so covered with buildings and heaps of waste rock that very little can be seen of the immediate surroundings of the ore deposit, and the large pit is of course full of water. The waste rock includes some norite and gabbro, but much more greenstone, such as hornblende porphyrite and fine-grained hornblende schist, as well as quartzite. The walls of the open pit consist mainly of green schist, including some masses of quartzite, but on the northeast side what is apparently a projection of gabbro from the large area to the north reaches the opening. The norite to the north is the usual coarse-grained kind with quartz and biotite, and, according to Dr. T. L. Walker, extends to the shore of Whitson lake where it gradually changes to gneissoid granite. The gabbro or norite band is flat and low, contrasting with the rough ridges of greenstone and quartzite to the southeast. As the surface is so much covered the description of the surroundings of the ore body as seen in the early days by Dr. Bell may be quoted:

"The ore consists of a body of mixed chalcopyrite and nickeliferous pyrrhotite mingled with more or less rock matter, giving the whole the appearance of a conglomerate. The general strike of the country rocks is here as elsewhere in the vicinity about northeast and southwest. The ore-bearing belt, which is associated with a dark quartz-diorite, is about 100 feet wide and dips northwest at an angle of 65°. It is overlaid by a massive bed of ash-colored graywacké, the weathered surfaces of which present raised reticulating lines. Immediately to the northwest of the shafts there is a dike from 30 to 50 feet wide, of dark brownish gray crystalline diabase, weathering at the surface into rounded boulder-like masses, which scale off concentrically."

The open pit is said to be 60 feet deep, and the lower workings of the mine reach a depth of 172 feet; but the plans of the mine appear to have been lost, so that the shape of the ore body cannot be definitely given. It may be mentioned that the rock dump is unusually free from ore, showing that the separation of the ore from the waste rock was carried out more carefully than at other mines in the region.

The Blezard is the last mine toward the northeast which has been worked on any large scale along the basic edge of the main nickel range, though several prospects and small workings are found beyond this toward the east.

The road from Blezard north past Whitson lake (locally called Blezard lake) gives a good section of the nickel-bearing eruptive, which is here only two miles and a half wide. A similar section is displayed along the shores of the lake, as described by Prof. Walker.[25]

The basic edge at Blezard mine is of the typical sort for the southern range, consisting of dark gray norite with bluish quartz and some plates of biotite. A wide swamp intervenes between the outcrops near Blezard mine and the hills to the north, where rock once more appears; and the character of the rock is still that of norite, though coarser in texture and paler in color than at the mine. After a short interruption of pale flesh-colored, fine-grained rock, probably a mass of metamorphosed quartzite, a coarse flesh-colored to gray variety of the eruptive is again encountered, either a syenite or diorite in appearance. A sharp hill of reddish gneissoid rock rises just beyond this, possibly a band of later granite, though it is sheared into a distinct gneiss. Next comes a dark flesh-colored variety of the eruptive, suggesting syenite, but proving under the microscope to consist mainly of pegmatite with much quartz. Coming down to lower ground near the northwest end of Whitson lake a darker gray rock, sometimes gneissoid, represents the acid edge of the eruptive and stands in contact with the sediments.

[25] Quar. Jour. Geol. Soc., Vol. LIII, (1897), pp. 47-56.

At the edge there is a narrow band of conglomerate containing pebbles and boulders of quartzite, granite, and perhaps other rocks, with some green chloritic schist, partly as matrix and partly without pebbles. There has been a good deal of crushing along the margin of the eruptive, and the relationships are not always clear, but the strike is about 60° with a dip of 35° to 55° to the southeast, as if the eruptive had overturned the edge of the sediments. Beyond the contact tuffs of the usual kind are found at various points along the road.

The Frood-Stobie Offset

The Stobie mine and its surroundings are probably best taken up in association with the Blezard and Mt. Nickel mines, its nearest neighbors to the north, though no surface connections are known between this important offset and the main nickel range, later granite and older greenstones intervening for a width of about a mile between the two.

The Frood-Stobie offset runs for a little less than two miles from southwest to northeast parallel to the main range, beginning as a narrow gossan band in lot 7, con. V, of McKim township, and ending at the Stobie mine in lot 5, con. I, of Blezard. The gossan is first seen about four miles northeast of Lady Macdonald mine at the upper end of the Copper Cliff offset, with which it probably has no connection.

Beginning at the southwest the rusty surface of gabbro is first encountered about 1,100 yards from the Frood as a band indistinctly separated from the adjoining rock, which is graywacké and schist, often containing large pseudomorphs after staurolite. The band rises as a ridge which is generally red-brown from the gossan, but is cut off by a narrow interruption of quartzite 600 yards southwest of the mine. The rusty gabbro quickly rises again and widens greatly, until near the mine it reaches its greatest width of about 200 yards. In this part it has quarzite and graywacké to the southeast, striking 40°, about the direction of the norite band itself. On the northwest the rocks adjoining it are more varied, but the rock in immediate contact is generally diorite. Beyond these rocks, which rise against each side of the gabbro, there are broad swamps. To the north of the mine the gabbro hill dips down quickly into swampy ground, and is presently cut off by quartzite and green schist. Beyond the swamp to the northwest at about 200 yards distance a chain of granite hills runs parallel. The granite is rather fine-grained, flesh-colored, and appears to be a part of the later granite mass observed near the Murray mine two miles to the west.

At the Frood mine or No. 3 belonging to the Canadian Copper Company, the gabbro rises about 90 feet above the low ground around, showing an eruptive contact with the graywacké and quartzite on its flanks, but the hill is so covered with gossan that boundaries are not easily fixed. The mine has been opened up by two large open pits and a shaft, and the ore is irregular in its occurrence and greatly mixed with rock matter, the large dump showing chiefly norite and graywacké, but also some blocks of actinolite and talc, no doubt secondary products. Angular and rounded masses of rock are enclosed in the ore as matrix, one pebble being of white quartzite, but these pebbles and boulders are probably the result of rolling between faulted surfaces.

This mine is on the southeast side of the widest part of the norite band, and a small open pit to the north shows typical pyrrhotite-norite, with every mixture of the two materials; while rusty surfaces extend all across the band to lot 7, where another company has done a small amount of development work on the northwest side of the ridge. The ore here seems greatly mixed with rock. Stakes placed at regular intervals over the ground show that a magnetic survey has been carried out, but the results do not seem to have justified further work.

This part of the offset, with a small band of graywacké to the southeast and of greenstone to the northwest, rises as a narrow ridge from swamps on each side and ends a little north of Frood mine, being cut off by green schist. Beyond it a very

narrow band of norite or of gossan-covered surface runs for more than half a mile northeast, with a narrow strip of greenstone mixed with graywacké beside it, and a wider band of graywacké between it and the range of granite hills referred to before as beginning at Murray mine.

About half way between the Frood and Stobie mines the band of rusty norite becomes discontinuous, and beyond this there are only patches of gossan-stained surface with a little fine-grained norite entangled in graywacké conglomerate and greenstone; the ridge sinking into the swamp. There is much evidence of crushing and shearing along this line, which must indicate a plane of weakness and more or less faulting through which the norite could intermittently penetrate.

There is a gap of about 400 yards between the last undoubted outcrop of norite and the gossan hill at Stobie which rises steeply with a still higher point of greenstone just to the south.

The Stobie Mine

The Stobie mine was one of the earliest discovered, and has been worked more extensively than any other except the Creighton, most of the ore having been taken from great open pits, though there are also underground levels, reaching a depth of about 250 feet. The ore body dips at an angle of 65° toward the west. The mine has been shut down since 1901, and the pits contain much water, but the main cavernous opening with its stopes and irregular projections gives an impressive idea of the size of the deposit, which is said to be far from exhausted, though more than 400,000 tons have been taken from it.

The mine is at the foot of the gossan-covered hill on the east side, and the enclosing rocks are of various kinds, including but little norite. The hill top shows a number of small patches of this rock with more or less ore embedded in a mixture of green schist, hornblende porphyrite, graywacké and crush conglomerate, as if squeezed up through a colander from beneath; and the whole hill, which is 330 yards in length from east to west and half as wide, is more or less gossan-covered, making the relationships difficult to determine. To the north there is swamp, to the west graywacké, to the south green schist and hornblende porphyrite rising still higher than the gossan hill, and to the east there are the great open pit, the mine buildings and the rock dumps, with a mixture of rocks showing between, including those previously mentioned, and also a patch of graywacké conglomerate undoubtedly formed by water, since the well-rounded pebbles are of great variety.

The openings at the pits show mainly graywacké, hornblende porphyrite and grayish schists with only a minimum of rather fine-grained norite. The only other rock observed about the hill is a small patch of reddish granite on the south slope, isolated as if part of the crush conglomerate. The large rock dumps consist chiefly of graywacké, often somewhat granitic or dioritic looking, and quartzite, with a little gabbro and a few blocks of chloritic or actinolitic rock. One block of diorite schist had been sheared along a number of planes which are now gilded with films of sulphide. The norite on the dump is often filled with shot-like grains of ore as at so many other mines in the region.

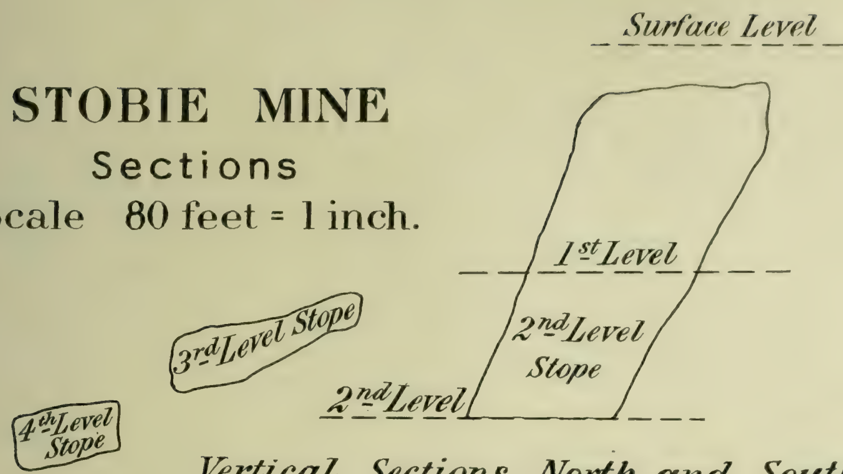
The offset has not been traced farther to the northeast, though a strip of swamp extending towards Blezard may conceal an extension in that direction, since there is considerable disturbance of the compass there. Where the swamp ends outcrops of greenstone, etc., bar the way to a direct connection with the main range. It may be that the widest part of the band, near Frood mine, was at first joined to the basic edge before the belt of granite was erupted between them.

It is evident that this offset differs from all the others in having no visible connection with a funnel-like bay of the norite edge. From the map it will be seen that the basic edge of the eruptive along this part of its course is unusually straight with

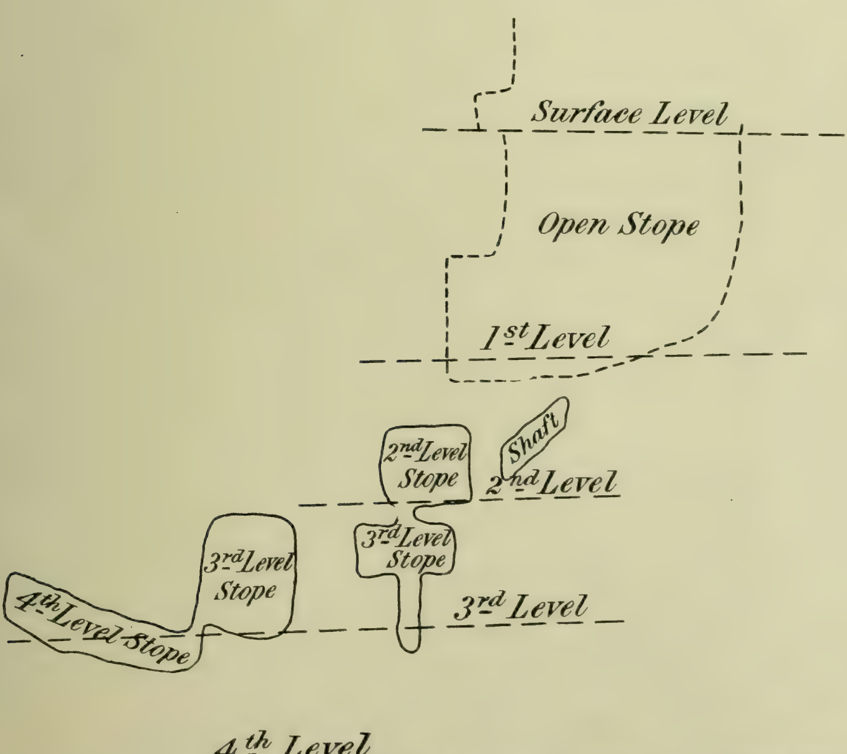
STOBIE MINE

Sections

Scale 80 feet = 1 inch.



Vertical Sections North and South



Vertical Section Northeast and Southwest

curves to the northwest rather than towards the offset. The basic edge parallel to this offset contains little ore, and it seems not improbable that there was a subterranean outlet for the ore, which made its way up through a line of shattering corresponding to the strike of the band of graywacké, which has the usual northeast-southwest trend.

The rocks adjoining this offset are of extraordinary variety, including both sediments and eruptives of interest. The graywacké so often mentioned sometimes contains well-rounded pebbles and shows cross-bedding. It merges into fine-grained gneiss in some places, and in others is crowded with large white pseudomorphs after staurolite of a very showy character. These crystals are often oriented parallel to one another, but at an angle with the schistose structure, which runs about 55° to 65° and must be of later date than the staurolites. Other parts of the graywacké contain concretions or pebbles of quartzite from the size of a pea to that of an orange, the larger ones usually having an eye and eyebrow arrangement, as if a crescent-shaped shell had split off and separated itself half an inch from the oval mass in the middle.

Along with these curious rocks there are smaller bands of conglomerate crowded with pebbles of various kinds and a few small outcrops of gray or pure white quartzite. Bands and small bosses of hornblende porphyrite penetrate these sediments, and are generally oriented to corespond with the strike.

To the north of Stobie and separating it from the main nickel range there are rugged hills mapped as greenstones, but really containing a singular variety of rocks, such as the older norite merging into greenstone toward the north, and more altered rocks toward the south, often what appears to be hornblende schist crowded with white bean-like quartzite with sharp outlines. With these occur larger white spots with a darker centre and even concentrically arranged orbicular forms with lighter and darker belts having a diameter of an inch or two. Pillow structure of an indistinct kind is found in places but scarcely amygdaloidal as near Elsie.

Northeastern End of Main Range

Beyond Blezard the norite contact sinks beneath the swampy border of a creek flowing into Whitson lake, and when it reappears there are few indications of ore until the Sheppard or Davis mine is reached in the south half of lot 1, con. III, of Blezard township. It is said by Captain McBride that a shaft 180 feet deep was sunk on this property, and that very rich ore was obtained from it, some assays running as high as 19 per cent. of nickel. The surface showing is not promising as to amount of ore, but the sulphides include a drusy reticulated mineral which weathers rapidly, perhaps polydymite. In the green schist a little south of the basic edge on this property a pit has been sunk on quartz containing some copper pyrites and marcasite.

In lot 12 of Garson, just adjoining the Sheppard mine the edge of the norite against green altered eruptives is schistose and contains fragments of the adjacent rock sheared out into short narrow bands.

Within the township of Garson the basic edge runs nearly due east along the southern side of concession III, and the width of the eruptive gradually increases eastward from two and a third to three and a half miles at the Cryderman mine. On the line between lots 11 and 12 greenstone is found as low hills to the south, the north boundary being lost under swamps; but a half mile east the contact is found a third of a mile north of con. II, just beyond the line between 10 and 11, and some gossan and ore occur in a pit sunk by Malbeuf and Martin. To the south of the pit there is well-stratified graywacké rising as low hills through a surface of rolling clay on which settlers are taking up farms. East of this no evidence of ore was seen until the Kirkwood mine was reached in lot 8; the low norite hills of pale gray color being separated by a strip of swamp from greenstones, sometimes surface lava flows with

amygdaloids and pillow structure. Neither rock forms hills of much height, the norite seeming as resistant as the greenstones, an unusual circumstance probably due to the squeezing of the norite and its re-arrangement to a somewhat schistose hornblendic rock which is not easily weathered.

At the Kirkwood mine a good deal of development work has been done including the sinking of two pits or shafts, now full of water, but fire has destroyed all the structures connected with the mine. The shafts are on hills about 100 yards apart, the western one seeming to be in greenstone 30 or 40 yards south of the norite, the other at the margin of very much sheared and crushed norite of a pale gray color, with somewhat banded greenstone to the south, the norite rising higher than the adjoining rock, which sinks into sandy drift-covered ground occupied by a farm. The rocks to the south are quite varied, graywacké and quartzite occurring as well as the greenstone, all frequently crushed to a breccia or conglomerate. At one point half a mile southeast of the mine a little patch of norite is found in the other rocks, having blebs and larger masses of ore disseminated through it, evidently a small discontinuous offset.

From the Kirkwood to the Cryderman mine the actual contact of the basic edge is hard to follow owing to drift and wooded country, but in general the norite is found not far to the north of the Huronian, the edge being more easily weatherd than the rocks on either side. The norite retains its sheared and altered character, and would hardly be recognized as the nickel-eruptive but for its continuity with the more characteristic rock to the southwest and its connection with ore bodies.

.Half a mile east of the Kirkwood property the rock south of the norite is largely a crush conglomerate of quartzite and graywacké, some bands of water-formed conglomerate containing pebbles having a strike of 110°

At the Cryderman mine on the south halves of lots 4 and 5, con. III, of Garson there is a larger showing of gossan than at the Kirkwood, and several pits have been sunk, one large and the others small, while a considerable amount of stripping has been done. The surface has been gridironed with pegs for a magnetic survey, the results of which are not available; and diamond drill cores lying about show that a good deal of investigation has been devoted to the property. The pale gray, somewhat sheared norite has a very irregular margin against greenstone and green schist, and shows the usual spotted appearance where blebs of ore have weathered out. Part of the norite is very fine-grained for the main range. The most important openings are near the margin, but the most southern outcrop is in greenstone about 200 yards south of the basic edge, evidently on a small offset.

The basic edge can be followed for a mile east of the mine with little change except for the lack of gossan and of ore, the norite still presenting the greatly squeezed and rolled appearance. Sand and gravel plains now begin to encroach on the boundary of the nickel eruptive, so that there are some gaps in our mapping.

A very good cross section of the nickel range is afforded by the road north of Headquarters toward the Blezard valley, the southern part of which was formerly the grade of one branch of the Emery railway. Most of the road is over sand and gravel, but there are numerous outcrops of rock ranging from the peculiar pale gray sheared norite to coarse dioritic material and dark or pale flesh-red schistose rock belonging to the acid edge.

In the township of Falconbridge, lot 7, con. IV, the basic edge turns north and has been followed here for over a mile with gneiss containing greenstone inclusions as the country rock. Four hundred and eighty paces east of the corner post between lots 7 and 8, on the line between concessions IV and V the most easterly point of the basic edge is reached, here gossany and lying against gneiss. Just to the south some stripping has been done and a small shaft sunk in rock containing thinly disseminated sulphides, principally pyrrhotite. As there is a southeasterly bay of the norite at this point one would expect a considerable body of ore, as on similar bays along other parts of the basic edge; and possibly future exploration may disclose such an ore body.

Acid Edge in Blezard and Garson

After swinging from nearly north at Azilda to nearly east where leaving the township of Rayside, the acid edge runs in about the same direction through concession IV of Blezard to the northwest bay of Whitson lake. Entering Blezard township the sharp hills of the acid edge sink into swamp before the contact with the Trout lake conglomerate, but a little to the east the meeting of the two rocks is well shown on the hilly region southeast of the flat farm land of Blezard valley. The conglomerate here is wide and characteristic, the edge next the eruptive being schistose and containing large granite boulders; the next layer to the northwest is a conglomerate or breccia crowded with rounded or angular pebbles of several kinds of rock; after which come softer tuffs with flattened pebbles sinking toward the plain. The acid edge is no longer schistose, as near Azilda, but has the normal granitic look.

To the east the acid edge follows low ground usually, cutting two small lakes in lots 9 and 11, and then turning a little northeast to Whitson lake, where the eruptive is grayish and schistose, as was mentioned in describing the section of the eruptive from Blezard mine to Whitson lake. The conglomerate is here very narrow, only a few paces wide, and it as well as the tuff beyond it is very schistose. Similar relations are found on the northeast side of the lake, where the contact passes about a quarter of a mile from the outlet into Chelmsford creek. The eruptive is pale gray with a tinge of flesh color on weathered surfaces, but darker gray on fresh ones, and is distinctly schistose like the few feet of conglomerate next to it.

East of Whitson lake conditions are much the same as far as the eastern side of Blezard township, the edge crossing into Garson township about a third of a mile south of the VI concession in very swampy country, which continues half a mile beyond. The acid edge turns somewhat north, entering the VI concession in lot 8, and then east again across the middle of the concession almost until it reaches the northeast corner of the township. The acid edge and conglomerate with part of the tuffs form a steep east and west range of hills with many swampy tracts to the north.

About half way across the township the eruptive rises as a cliff, reddish in color, felsitic in texture and penetrated by many small quartz veins. On lot 4 the acid edge is grayish and schistose with a wide band of schist conglomerate to the north, having a strike of 125°, and along the road from Blezard valley to Headquarters it rises as a steep hill from a gravel plain, formed of fine-grained reddish granite with a slight schistose structure running 110°. Here there is a gap of half a mile where no rock rises above the gravel.

Just within the southwest corner of Maclennan township there is a small outcrop of rock at the acid edge where the old railway grade ends in a glacial kettle mostly surrounded with sand and gravel. The acid edge here is schistose with a strike of 110° or 120°, and next to it is the ordinary schist conglomerate, followed to the north by a ridge of tuff. To the east of this a gravel plain and morainic ridges hide the solid rock for a long distance; but the acid edge must turn sharply north or northeast, since it is next found in lot 3, con. III, of Capreol on the northern range.

THE NORTHERN NICKEL RANGE

Introduction

The northern nickel ranges, as known to the prospector, were not continuous, but had large breaks where no gossan or ore deposits had been found, as in Morgan township and near Windy lake; so that it required careful geological exploration to follow up the band of nickel-bearing eruptive and fill in the gaps. This has succeeded so well that the northern and southern ranges have been proved to connect at the ends without a break, unless, very improbably, there should be an interruption beneath the sand and gravel plains of Capreol and Maclennan, where direct evidence is lacking for two or three miles.

The basic edge of the nickel eruptive has, of course, been followed with special care because of its economic importance as the bearer of ore deposits, but the acid edge has been studied in some detail also, since the width of the eruptive has been found to have an important bearing on the probable occurrence of ore bodies, a very narrow part of the range seldom showing any gossan and never ore bodies of workable size, while very wide parts are almost invariably accompanied by ore deposits of importance.

In the older maps the northern nickel range was represented as forking about the middle of Bowell township, one band running west to the middle of Foy and the other southwest toward Morgan township. Which of these norite bands formed the basic edge of the range was uncertain until our work proved that the southwestern one joins the range already known in Levack township.

The northern range as here described will be considered to include everything north of the Sultana mine in Trill at the west end, and of Falconbridge at the east end of the eruptive basin; and the work will be taken up at the western end, following the range eastwards. The northern range as thus defined has an irregular northward curve, its basic edge is 54 miles long; while the basic edge of the southern range is only 40 miles long, the doubtful part where the gravel plains cover the rock being omitted from both. The relative importance of the two ranges is however very different, since the northern range is on the average much narrower than the southern one.

The Nickel Range in Trill

Rounding the bend made by the basic edge of the nickel-bearing eruptive less than a mile west of Sultana mine the actual contact is lost under swampy tracts, though the acid edge is well defined to the northeast, and the Laurentian with some patches of greenstone occurs to the southwest and west. An old wagon road whose corduroy is almost rotted away follows the edge somewhat closely, having been made by prospectors who did some development work years ago on locations taken up to the north.

Trillabelle Mine

In the third concession on the line between lots 10 and 11 of Trill there is a fairly well beaten trail or portage running east and west connecting with a canoe route eastwards to Fairbank and Vermilion lakes; and here just to the west of the old wagon road granite of a Laurentian aspect rises as a rocky hill above the swamp so usual at the basic edge of the nickel-bearing eruptive. Next to this, going north, is a dark-green rock containing some boulders, evidently a Huronian conglomerate or breccia, and against it ore is to be seen. Half a mile farther north the wagon road ends at the mine called by our guide the Gillespie, but in the Bureau of Mines report the Trillabelle, where a considerable amount of work was done many years ago.

Here and 170 paces beyond are a few foundations of stone, remains of a hoisting plant and various log houses; and ore or gossan against the hill which rises to the west. The rock observed is mainly greenstone with boulders suggesting a crush conglomerate, though a gray fine-grained rock near the northern pits may be norite. The dip of the rock face against which the ore lies at the points previously mentioned is from 35° to 45° to the east.

Half a mile north morainic hills conceal the bed rock and the next outcrop observed is probably the basic eruptive edge, the rocks higher up the hill to the west being bouldery greenstones like those mentioned before.

For a distance of 550 paces east of the line between lots 10 and 11 and near the middle of the fourth concession the rocks observed are a somewhat re-crystallized arkose, evidently Huronian, and beyond this only bouldery drift is seen for 200 paces, probably covering the basic edge of the nickel-bearing eruptive, which here rises from under the drift.

To the north of the fourth concession the basic edge is hidden by wide swamps, though it is known to run to the east of Armstrong lake where Laurentian granite crops out; and the exact edge has not been visited in lot 8 in the I concession of Cascaden, though basic looking norite occurs to the east of a narrow lake which cuts off access to a location taken up years ago on the opposite side of the lake, said to contain ore. The northern arm of this lake marks the boundary between the norite and Laurentian rocks consisting of gneiss and greenstone. From this point to the northeast the basic edge is most easily reached by a trail from the southwest bay of Windy lake, which runs largely over drift deposits including a moraine, but gives access to outcrops of rock.

The basic edge is nearly straight from this point in a northeasterly direction to the bay just mentioned, and on Windy lake itself the northwest shore, where not drift-covered, is Laurentian of the usual kind in the region, consisting of reddish or grayish bands with darker gray layers of finer grained schist. The islands off shore and the large peninsula projecting from that shore are of norite. On the peninsula the boundary is largely hidden by morainic and esker ridges, but it is distinctly seen on the shore of the southwest bay. The rest of the shores of this beautiful lake are of norite or the intermediate rock between the basic and acid phases.

The best section of the nickel-bearing eruptive is provided by the railway cuttings to the west and east of the little station Onaping; and a number of rock specimens from these cuttings have been described by Prof. Walker.[26]

Beginning on the northwest near Windy Lake station, which is some distance west of the lake, Laurentian granite and gneiss with darker schistose inclusions are found until the shore of the lake is reached. when gray dioritic-looking norite occurs, the actual contact however being hidden by drift. The rock remains the same in appearance for 100 yards, but soon changes to a reddish syenitic phase of fine or coarse grain, which continues to Onaping station, and is followed toward the southeast by greenish-gray rock having a peculiar ophitic-looking structure. The color and general appearance of the eruptive at the ends of this section are much alike, but the intervening phase of flesh-red syenite-looking rock is very different.

The acid edge of the eruptive rises as very steep hills to a height of 300 feet above the station, and the railway is forced to follow the valley of Onaping river in a sharp curve in order to cross the range of hills. The southeast side of these hills consists of hardened sediments, at first gray, fine-grained graywacké conglomerate with pebbles and a few boulders of quartzite and granite, and sometimes also of gray chert, extending along the railway for about 1,000 feet; and followed by characteristic black vitrophyre tuff, often crowded with small fragments of gray material.

Acid Edge, Ross Lake to Windy Lake

The nickel eruptive gradually widens from the northward bend to the northern part of the township of Trill, and then narrows slightly as it approaches Windy lake. The acid edge near Ross lake is fine-grained, gray and not schistose, but to the northeast it becomes dark green and schistose, as on Fairbank lake which has already been described. The conglomerate is not very prominent along this part of the contact, the tuffs coming close to the acid edge, if not actually touching it.

Along the acid edge in Cascaden the norite is not schistose and is paler gray in color than at the previous locality, sometimes slightly reddish. The conglomerate is much more prominent here, at the very edge looking like Laurentian, a fine-grained confused gneissoid rock with coarser patches in it, representing granite boulders, coming first, followed by less metamorphosed rock looking like Huronian conglomerate, with pebbles and boulders of granite. etc. Next comes a grayish, very fine-grained rock, like some graywackés, more conglomerate or breccia, and finally the tuff.

26 Quar. Jour. Geol. Soc., Vol. LIII (1897), pp. 56-59.

Very similar relations are found at the acid edge half a mile south of Windy lake in lot 12, the eruptive, which is flesh-colored on weathered surfaces, seeming to blend into the Laurentian-looking conglomerate. The railway section, on the other hand, shows a grayer acid edge and little conglomerate.

In general one may say at this end of the basin the acid edge is more granitic in appearance when the conglomerate is wide and contains many granite boulders; and is dark green gray and very fine-grained where the conglomerate is thin or practically wanting. Is the darker color due to absorption of part of the black tuff in the latter case, by Dr. Daly's overhand stoping?

Acid Eruptive, Windy Lake.

The region of the acid edge just described is exceedingly hilly and rugged, more so than at most points on the acid edge of the southern range described in earlier chapters.

Levack Ore Deposits

To the northeast of Windy lake the basic edge may be traced, with some interruptions from gravel plains, to Onaping river; but no gossan or ore was observed between the Gillespie mine in Trill and the Onaping river in Levack townhsip. The old mining road from Onaping to the Levack ore deposits is now in very bad condition from the heavy teaming of the lumbermen operating in the region, and also from flooding, due to their dams on the lakes intended to sweep down the logs in the somewhat shallow river and its tributary creeks. A diamond drill plant was taken along this road to the Strathcona mine during the summer of 1903 for the Lake Superior Power Company, but the difficulties met in transporting the heavy machinery were very great. The road leads along the river from the station for about 2½ miles, largely over gravel plains, then crosses a bridge and follows the valley of a tributary toward the northeast, keeping along the foot of a range of Laurentian hills just at the margin of the norite. The actual margin is often occupied by small, narrow lakes, as though the norite had decayed more rapidly than the granite; and at several points where the

norite still rises above the general level it is now weathering extraordinarily fast. The best instance is near the dam at the mouth of the creek draining Moose lake into the Onaping, where the spheroidal weathering is of a very characteristic kind. The rock, which is gray and coarse-grained, is irregularly fissured into blocks from 2 or 3 to 20 feet across. The weathering takes place along the fissures, leaving mound-shaped surfaces with channels between; and may go so far as to leave rounded blocks resembling drift boulders resting on the decayed surface, with material like fine gravel beneath the block, representing the products of decay. In many cases the actual margin of the norite is not to be seen, but Laurentian rock rises to the northwest out of a lake or swamp, and norite to the southeast.

About four miles from Onaping along the road just mentioned thick beds of gossan lying against the Laurentian attract attention at the Tough and Stobie property and test pits show that some ore underlies it, though no norite is to be seen. The Laurentian is of the kind usual in the region, granite running into gneiss and greatly mixed with fine-grained greenstone; and the ore, which consists of pyrrhotite, with a little chalcopyrite, sinks beneath the surface of the muskeg through which the creek winds.

Waterfall over gneiss west of Onaping.

The underlying Laurentian dips 33° to the southeast, and a little projection of rock near the top of the slope seems to have protected the ore beneath, which is now however largely turned to gossan. A hill of norite rises a quarter of a mile away beyond the muskeg, but none of the rock is to be seen where the stripping has been done.

Less than half a mile farther along the road there is another outcrop of gossan and ore like the first one, but with a lower hill of Laurentian on the northwest and a small lake on the other side. A little beyond this lake there is a gap in the Laurentian hills, suggesting an offset, and it is said that an ore body has been found some distance out in the granite, but we found no trail to it, and left it unvisited. Beyond

this apparent offset there is another marginal lake, and then the route passes through low hills to what was once called the Levack mine, in lots 1 and 2 in the fourth concession at the end of the wagon road, about nine miles from Onaping.

Here two properties, the Strathcona and the Stobie No. 3, or Big Levack mine, have been opened up by stripping and test pits, and have been surveyed magnetically as shown by the systematically arranged survey pegs.

Strathcona Mine

Mr. Ernst A. Sjostedt, who examined the Strathcona property some time ago, reports on it as follows:

"The mineral zone runs diagonally N. E. and S. W. across the north half of lot 3 and south half of lot 4 in the fourth concession of Levack township, and is bounded to the northwest by a range of syenitic granite, with which it forms a direct contact, and to the southeast by a wide range of norite, which usually forms one side of the mineralized zone throughout the Sudbury district. The largest body of ore is shown at the northeast end of lot 3, although the line of magnetic attraction is practically continuous across both lots, and ore is shown at various points on lot 4 as well. Near the northeast end of lot 3 the principal prospecting work has been done, a space of 3 or 4 acres having been cleared of timber and underbrush, and in places the formation stripped, exposing the capping and gossan, which generally reaches a depth of 2 to 8 feet. Part of the ore body is here shown up by a number of cuts and pits, also by two shafts, of which No. 1 shaft is 45 feet deep, passing 8 feet through barren cap rock, then through 25 feet of mixed ore, then through 12 feet of solid pyrrhotite, and a 10-foot hole having been drilled in the bottom of the shaft, showing clean ore the entire distance. No. 2 shaft (250 feet north of shaft No. 1) is 30 feet deep, 6 feet being in cap rock and 24 in solid pyrrhotite.

"Pit A (320 feet north of shaft No. 1), and pit D (40 feet north of pit A) show ore within 2 feet of the surface, and trench C, along a low hill-side about midway between pit A and shaft No. 2, shows a face of ore 50 feet long, in the centre of which a pit was sunk through 12 feet of solid ore.

"From the data furnished by the above mentioned pits and shafts, covering an area of about 600 feet in length and width, the amount of ore in sight on lot 3 is some 60,000 tons, but this includes an area of less than a tenth of the ground covered by equally promising surface indications, consequently there is every reason to expect a much larger body. The ore exists mainly in solid masses within a zone of 200 to 600 feet wide, and some 1,400 feet long.

Following are a number of analyses of samples taken from the above mentioned workings, which will show the character of the ore."

Sample from	Sampler.	Insol.	Fe.	Cu.	Ni.
Shaft No. 1, 8 feet from bottom	D. C. Schuler	....	....	.57	2.78
" piece from dump	E. A. Sjostedt	....	....	1.35	3.55
" 2, from dump	D. C. Schuler	....	....	.70	3.85
" 25 feet depth	"	5.03	....	2.11	3.54
" piece from dump	E. A. Sjostedt	....	....	.14	4.65
Pit A, surface	D. C. Schuler	....	....	.67	2.24
" B, surface	"	....	....	5.47	2.02
" B, bottom	"	6.10	....	1.54	3.37
" C, surface	"	....	....	.33	2.40
" C, trench	"	3.40	....	1.24	3.27
" C, 13 ft. pit	"	....	....	.28	2.72
" D, low ground	"	4.00	50.4	.30	3.21
Diamond drill hole, near A, 26 ft	A. B. Wilmott	....	....	.65	3.80
" " 40 ft	"	....	....	.58	2.60
Shafts, all over dumps	R. H. Aiken	5.01	54.3	2.23	3.15
Near norite wall	"	....	....	1.49	1.68
"	"	....	....	2.43	1.70
Average	....	4.71	52.3	1.31	2.97
Samples taken by Messrs. Cohen & Bradley, experts for J. R. DeLemar, N.Y.	....	....	....	1.99	2.67
Total average	....	....	....	1.70	2.82

The Big Levack mine just to the east of the Strathcona presents a very irregular margin of gossan and ore spread over Laurentian hill-slopes and sinking to the southeast under muskeg with a dip of about 20 degrees in some places, but steeper in others. Some norite is present mixed with the ore; most of it, however, and probably also of the ore, has been weathered away, but may perhaps be found beneath the swamp.

The sceond set of mines seems much more extensive than those nearer Onaping. Beyond the Big Levack mine the nickel-bearing eruptive bends off to the east in swampy ground with small lakes, and only one small patch of gossan was observed on its border.

Moose Lake Region

The acid edge of the nickel-bearing eruptive in Levack and the northeastern part of Dowling is best studied from Moose lake, which spreads out irregularly over a length of three miles along this margin. Moose lake may be reached by a road running northeast from Larchwood to Joe Seemo's farm on the banks of the Onaping river near its junction with the Vermilion; and then by a trail leading through the woods to a bay on the line between Levack and Dowling townships. From the river to a pond with no outlet near the bay only drift is to be seen on the portage, but the acid phase of the eruptive here shows itself, and practically the whole of Moose lake is enclosed in it. The outlet of the lake into the stream mentioned before as joining Onaping river two miles north of the station is over the eruptive, and the same rock is found at various points on the lake and on the next small lake to the northeast, generally called Trout lake, and another to the east of it.

The acid edge runs northeast and southwest as a range of hills often with sharp minor ridges, sloping to the southeast and precipitous to the northwest, resulting perhaps from faulting during the sinking of the basin, or possibly representing a main direction of joints. All the survey lines cross these ridges diagonally. The contact of the nickel-bearing eruptive, with the tuffs to the southeast is often drift-covered, and on this edge as well as on the basic edge there is frequently a valley or narrow lake in this position. The sedimentary rocks to the southeast also form sharp ridges parallel to the eruptive ridges, and occasionally a narrow hill consists of the acid edge of the eruptive on one side and on the other of tuff.

The best exposure of the contact between the acid edge and the sediments found in the region occurs on the shore of a pond a little east of the end of the portage from the south to Moose lake. This body of water, unlike most others, cuts across the strike, and near its outlet into Moose lake the edge of the nickel-bearing eruptive shows a reddish-gray medium-grained rock, followed to the southeast by coarse flesh-red granite or gneiss, possibly a pegmatite dike. Then comes rock much like the first mentioned, succeeded by conglomerate with a fine-grained gray crystalline base and granitic-looking pebbles, lasting for about 120 feet, doubtless the basal beds of the sedimentary series. Beyond this is coarse white quartzite for about 70 feet, and then conglomerate again for about 200 feet, after which there is a curious breccia of paler and darker chert with some pebbles and boulders of granite for 1,000 feet, evidently the same as had been found along the railway southeast of Onaping beneath the vitrophyre tuff.

Morgan Township

The basic edge of the eruptive crosses a small lake just east of the Levack mine and enters Morgan Township on the fourth concession line, then turns a little north of east to Island river, which follows the edge for more than a mile, and turns northeast once more to the fifth concession, finally passing into Bowell township from the northeast corner of Morgan township. The boundary may be reached partly from Trout lake and partly from a lumber road leading over sand and gravel plains from Chelmsford to a camp near the junction of Island and Sand Cherry rivers. Travel in

the region is, however, very troublesome from fallen timber and the unusually rugged and precipitous hills along the contact. The best exposures seen are near the lumber camp, where a steep hill-side rises above Island river, having the nickel-bearing eruptive on its southern face pushing projections into the Laurentian rocks forming the summit. The former rock is not very gray, sometimes even rather reddish-looking, and of variable texture, coarse-grained and fine-grained parts running into one another, the finer grained material sometimes cementing blocks of Laurentian rock into a breccia. The Laurentian, which strikes east and west with a vertical dip, has the usual characters and consists of coarse gneiss with bands of gray-green finer grained material, the whole sheared in places into what looks like felsite. Near the edge it is greatly broken as if by the action of the eruptive mass to the south. No ore or gossan was found from the west edge of the township to lot 1 in the sixth concession, almost at the northeast corner, and prospectors have taken up no locations between the two points. Near a small lake where the four townships, Foy, Morgan, Lumsden and Bowell, meet there are two patches of gossan, on which very little work has been done.

The southern or acid edge of the eruptive in this township has the usual characters, and is in contact at various points with the basal conglomerate so often found below the tuff. The eruptive band is at its narrowest about the middle of Morgan township, having at one place a width of scarcely a mile, and there seems less variation in character between the basic edge and the central and southern parts of the band than it is customary to find in other parts of the nickel range. Perhaps this fact should be brought into connection with the absence of ore referred to above. The thickness of the molten eruptive may have been insufficient to provide any large quantity of sulphides by gravitational segregation.

In Bowell Township

In Bowell township the northern nickel range has long been known through the work of prospectors, and a row of locations has been taken up beginning at the southwest corner and running quite across the township, passing in the third concession into the next township, Wisner. About at the centre of the row of locations a long offset branches toward the west, extending out of Bowell into Foy, and ending almost exactly in the middle of the latter township; and the whole of this offest is included in mining locations also, so that there has been more interest shown in ore deposits of this township than in any other on the northern range.

The locations are best reached by colonization and lumber roads from Azilda (Rayside) to Trout lake (a larger body of water than the one of the same name in Morgan township). Crossing Trout lake by canoe a trail leads inland from its northern bay and branches toward the southwest, west and northeast. A part of this trail which was cut out for the use of pack-horses during the development of some of the properties is still in good condition, but towards the ends in each direction the path is rough and hard to follow, especially where the timber has been cut and fire has run.

Beginning at the southwest corner of the township the basic edge of the nickel-bearing eruptive is found a little north of the corner post of location W D 251, and in a general way the trail follows the edge, except where hills or swamps turn it aside, or where morainic ridges hide the contact. Gossan shows against the steep slope of the Laurentian toward the northeast corner of the location, and there is a swampy pond below, with hills of norite to the southeast. Near the west end of W D 241 an outcrop of gossan and a test pit along the trail indicate the boundary, and more gossan is seen toward the east side of the location, then drift hides the contact until W D 231 is reached where three similar small outcrops of gossan and ore occur against the Laurentian.

In W D 238 a small offset projects northward from the edge, running into a narrow valley in location W D 37, where there are strippings showing gossan. The

valley is enclosed by steep and bare Laurentian hills. A small lake in location W D 242 and 239 appears to represent the boundary, and Roland lake a little to the northeast occupies the same position, having Laurentian on the north and norite on the south.

In a general way there is a valley running along the southeast edge of the Laurentian, which rises as a very rugged range of hills to a height of from 200 to 270 feet, with patches of ore along its foot. Southwest of the valley, which is often occupied by a narrow lake or muskeg, gray hills of norite rise to about the same height as the Laurentian.

In W D 35 the offset running to the Ross mine in Foy leaves the edge of the main range. In W D 36 near its northwest corner and probably extending into the previous location there is a promising outcrop of gossan and ore at the edge of the granite, but east of this to Trout lake no ore was observed.

Offset to Ross Mine

The longest offset on the whole circumference of the nickel-bearing eruptive extends for six miles nearly westwards from W D 35 to W R 5, reaching what is called the Ross mine, in the exact centre of the township of Foy. The path is at first good, but before the west boundary of Bowell township is reached fire and fallen timber and the debris left by the lumbermen injure it greatly, and beyond this care is needed in following it even in green timber, since it has scarcely been used for a number of years and the blazes are growing dim.

Just after turning off from the main range there is a considerable showing of ore on a hillside, and the adjoining rock consists largely of white plagioclase crystals so crowded together as to appear like anorthosite. Small seams of magnetite occur in this rock as well as sulphides. To the northwest in W D 150 a wide expanse of gossan is exposed by stripping and numerous test pits extending nearly to Nickel lake, where there is a log house occupied during the development work. Turning west the band narrows greatly and fine-grained norite penetrates between blocks of coarse-grained norite, of a gray gneissoid rock, of greenstone, and of a white rock with porphyritic feldspars, the whole rusty or gossan covered. The adjoining Laurentian is coarse red granite, an unusual variety in the region. On the shore of the next lake to the west a similar mixture of rocks is seen, and some gossan rises above the water.

From this point to the neighborhood of Ross mine little ore or gossan was seen, although the band of norite, narrowing and widening, seems to be continuous or nearly so the whole way; but somewhat similar outcrops of gray rock rising through drift-covered ground leave some doubt as to the relationships. Evidently the early prospectors considered the whole length to belong to the nickel range, or they would not have taken up locations along it. The greatest width of the offset, so far as observed, is in W D 234, where the rock seems to extend for about 500 feet, but usually it is much narrower, in one case apparently only 20 feet.

Our exploration of the locations just east of the Ross mine was greatly hindered by the work of a colony of beavers, which had recently built a dam backing up the water for half a mile or more in various directions into the flat wooded land along the creek. W R 5, the original Ross mine location, includes two outcrops of ore and gossan standing as usual against a hill-side of Laurentian, and dipping under the muskeg borders of a small lake; but the amount of ore to be seen is not large. It is reported to assay 2.75 per cent. of nickel.[27] Most of the Laurentian encountered along this offset is coarse-grained and flesh-colored, but some masses of gray-green rock, in general appearance not unlike the norite, are enclosed in it.

[27] G. S. C., 1890, Part R, pp. 43-4.

South Edge of Eruptive

The acid edge of the eruptive crosses from Morgan township into Lumsden in the fifth concession, and is fairly well exposed near the north shore of a small unnamed lake just north of the concession line in lot 9, as a gray rock weathering reddish. The neighboring sediments to the south look like quartzite with pebbles and merge into tuff, and these rocks continue to the northeast as a range of high hills, sinking, however, where Nelson river makes its way through. Along this valley gravel plains and morainic ridges conceal the rock. On the line between lots 6 and 7 to the south of a small lake crossing the concession line between Lumsden and Bowell the acid edge forms a hard grey-green rock, or some other eruptive appears to intervene between it and the sediments; but on the town line in lot 5 and also in lot 4 we find the usual relationships, the granitic-looking acid edge seeming to blend with a greatly metamorphosed coarse conglomerate. In places, if it were not for the coarser grain and different texture of the included pebbles and boulders, the matrix of the conglomerate could not be distinguished from the eruptive, and great care was necessary not to overrun the contact between the two rocks.

In location W D 252 at the southwest bay of Trout lake there is once more a fine-grained dark-green rock between the eruptive and the tuff, in places very much like a basic eruptive rock itself, but in others charged with a few pebbles of granite, and having the characters of "slate conglomerate." In this marginal rock there are veins containing quartz with zincblende, galena and a little copper pyrites, and at one point a shaft has been sunk to open up the ore. The quartz formed quite large crystals before the sulphides were deposited, and on breaking the ore the six-sided cross sections of the prisms are well marked. No very large amount of ore was to be seen and the deposit does not seem to be of great importance so far as the present development work goes.

There is a small opening near a blacksmith shop a little east of the east bay of Trout lake, also on similar dark-green eruptive-looking rock, but even less ore is to be seen here than in W D 252. These small ore-bearing veins are found in the adjoining sediments or in greenstones connected with them and not in the nickel-bearing eruptive itself, but the eruption of the latter may have some connection with the formation of the deposits.

A very good section of the contact of the acid edge with the sediments is exposed on a small peninsula projecting from the south shore of Trout lake where the lumber road reaches the water. Two or three islets to the north show the nickel-bearing eruptive in its usual phase along the southeast edge, while the peninsula ends in a conglomerate having apparently two kinds of matrix, fine-grained green material containing epidote and quartz, and rather coarse reddish or grayish quartzite, both including many small and large pebbles of granular quartzite and of granite. Irregular projections of the acid edge granite penetrate the conglomerate for 100 yards or more. Next to the southeast is a narrow range of precipitous hills of hard splintery cherty-looking brecciated rock, then comes a breccia of a less cherty kind, with, however, a few granite boulders, probably the base of the tuff. The section described is about 1,200 feet in length. Still farther to the southwest is the usual tuff, less flinty and unaffected by the neighborhood of the eruptive.

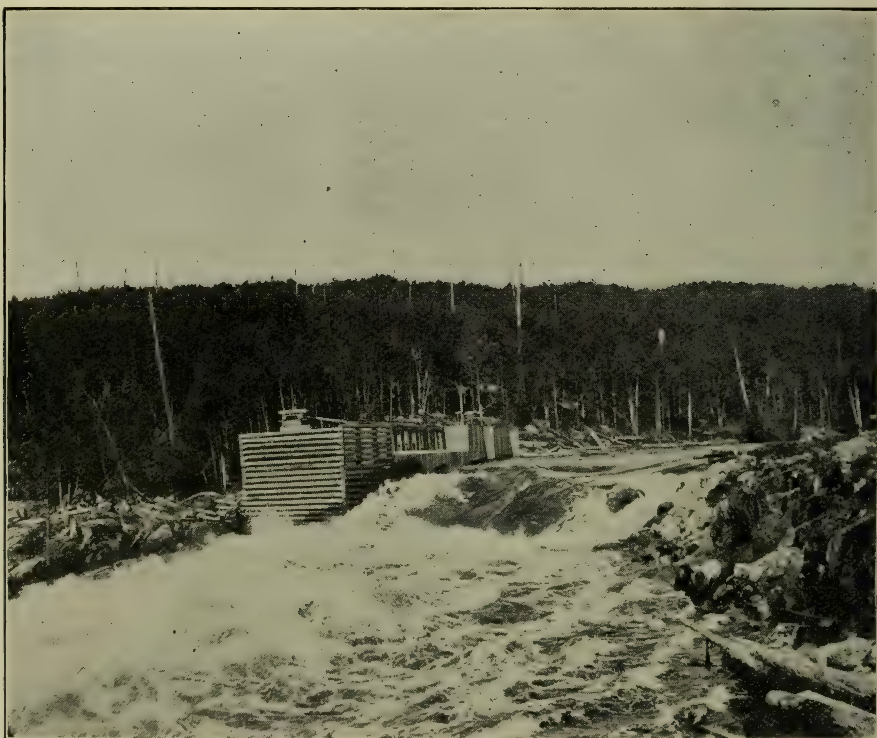
Wisner Township

The basic edge of the eruptive runs almost due east from the northern side of lot 12 to lot 4 in the third concession of the township of Wisner, and then bends to the southeast toward Vermilion river and Norman township. The portion up to lot 4 has been surveyed as locations, but prospectors seem to have found no ore along the rest of it. This part of the nickel range is best reached by lumber road to Frenchman's lake and then by a canoe route to Joe's or Marion lake which crosses the nickel-bearing

eruptive diagonally. The two Frenchman's lakes are in the sedimentary rocks, the south end being enclosed in the soft black slaty variety of the tuff, but morainic materials hide the bed rock as one crosses to Joe's lake.

The basic margin of the nickel-bearing eruptive has the usual characters north of Joe's lake, the boundary to the north being Laurentian and a swampy valley running at its foot with low hills of norite to the south. Not much gossan or ore is to be seen in the locations across this township, though considerable showings occur on W D 16 and W R 14 near the head of the lake.

The acid edge is very well shown on Joe's lake, which it crosses near the south shore, and the bare surface of the rock near a small lake to the southwest gives an uninterrupted section across the boundary. The edge of the eruptive is granitic-looking and seems to blend into a conglomerate with a fine-grained crystalline ground-mass which might be taken for granite containing small and large boulders of granite, often with vague edges. This conglomerate is penetrated by indistinctly bounded projections



Falls on Vermilion river at power plant.

from the eruptive, and seems to have been greatly re-crystallized in consequence of its presence. About 360 feet to the south the conglomerate has a ground-mass suggesting arkose or quartzite with a few pebbles of granite, and this dips beneath the small lake.

A parallel section on the shore of Joe's lake shows a similar conglomerate followed by breccia-like tuff at a distance of 400 feet south of the acid edge, but with a few feet of a fine-grained green-gray rock without pebbles between.

The eastern side of Wisner township is most easily reached from the Vermilion river near Dawson, and a canoe route leads across from the second Frenchman's lake to this point. The rock showing between the two lakes is mainly tuff, but half a mile west of Dawson a large dike of diabase rises beside the trail, perhaps the continuation

of a dike found by Mr. Culbert on Onwatin lake about two miles southeast. Near Dawson gravel plains and muskegs cover the rock along Vermilion river, but the norite forming the northern edge of the eruptive is found rising as hills a mile west of the upper end of Bronson lake, near a small lake at the corner of lots 3 and 4 in the fourth concession of Wisner township. At the boundary the norite leans against a Laurentian hill, but no ore or gossan was to be seen; and similar relationships are found to the northeast towards Vermilion river, but gravel terraces hide the rock nearer the river.

Near the head of Bass lake, the next expansion of Vermilion river south of Bronson lake, the acid edge shows itself with the usual metamorphosed conglomerate to the south, here having a width of 800 feet before the tuff is encountered.

Norman and Capreol

The boundaries of the nickel-bearing eruptive in these townships were mainly fixed by my assistant, Mr. Culbert, and the following account is given in his own words:

"The northern nickel range makes a sharp turn in the township of Norman, its outcrop there assuming a southward direction. In the northern concessions of Capreol township another change in direction is found, the strike being northwest and southeast to Massey creek as far as it was followed. The line of outcrop of the basic edge, owing to its comparatively rapid weathering, determines the position of a narrow valley from the Whistle property to Massey creek. This valley widens in many places, often containing lakes which conform to the strike of the eruptive. Examples are lakes Selwyn, Waddell, Ella and Clear.

"The basic phase along this part of its outcrop resembles the norite of the northern range, being a light mottled gray and is comparatively narrow. Darker phases occur in spots and resemble the rock at the Blezard mine, but the few small patches found near Moose lake are easily overlooked. Many peculiar contact varieties are found, such as the poikilitic kind near the Blue lake ore deposit, which to the eye appears quite coarsely granular, but is found under the microscope to consist of large aggregates of feldspar optically continuous with inclusions of bi-silicates. The transition to the micrographic phase takes place within a short distance, and the total width of outcrop of the eruptive is not great in the townships of Norman and Capreol, being less than two miles as a rule. The micropegmatite is of the usual flesh-colored rather coarse-grained variety found in the northern range and corresponds in mineralogical composition.

"On the east side the eruptive is in contact with Laurentian granite and gneiss. The granite is pinkish-red, with abundant quartz and few of the dark minerals in places where the acid magma has not incorporated inclusions and masses of earlier rocks. In many parts hornblende porphyrites and green schists occur, often running out in basic bands into the acid material and forming gneiss, or again occurring as immense blocks or large masses of considerable area which the action of the erupted material failed to shatter. A large mass of this kind occurs half a mile south of Moose lake near the small marsh on the road to Blue lake.

"The acid phase to the west comes in contact with the usual conglomerate, highly indurated with well-rounded pebbles and boulders of granite, greenstone, schist and quartzite. On passing westward this rock becomes softer and tufaceous, with no large boulders showing.

"A large diabase dike of great width, in some places a few hundred paces, was found in the valley of Massey creek on the boundary of Capreol and Maclennan townships in the third concession. It also outcrops on lot 5 in the fourth concession of Capreol on the shore of the small lake on the line between lots 5 and 6. This is probably the same dike that crosses lake Onwatin and which appears on lot 8 in the second concession of Wisner near the southwest post, the outcrops all being in a nearly straight line. The rock has a distinct green color due to a considerable content of olivine.

"Wherever the contact between the norite and the Laurentian appears on the surface indications of ore are found, either in thin patches of gossan or outcrops of ore bodies. Sulphide particles can be found on the contact wherever the rock is tested, and the red gossan product is present along its entire length in the townships near lake Wahnapitae. The more important outcrops of ore occur near Blue lake and south of it near the small Moose lake. On the shore of Blue lake the diamond drill has proved the existence of a body of ore of some size. The outcrop near Moose lake

shows a band of ore following the contact and varying in width from two to six feet of fairly good sulphides. In the test pits this ore appears rather lean, being mixed with some of the mother magma, but the proposition looks promising, having in view the improvement of transportation facilities. Further north, strong local attractions are found on the north end of Ella lake near the west side of WR 2, but no test pits have been opened to prove the existence of an ore body. The east side of Clear lake near the shore shows a few test pits with ore and a considerable extent of gossan."

The Whistle Property

A canoe route leads from Blue lake to the Whistle property, passing through the northeast end of Capreol township by Clear lake and Trout lake to Waddell lake and Selwyn lake in Norman township. The Whistle property is on lots 6 in the fourth and fifth concessions; and has been opened up by stripping and test pitting, showing an extraordinary extent of gossan surface, about half a mile in length from southeast to northwest, and 250 yeards wide at the widest place. So far as extent of gossan is concerned, this seems to be the largest exposure of ore in the district. The hill on which the stripping has been done rises 230 feet above the valley of McConnell creek to the southwest.

The norite in connection with the ore on this property is very fine-grained and mixed with fragments of other rock, almost forming a conglomerate with a matrix of norite. It seems to be broken or crossed by some dikes of granite and patches of greenstone; and the adjoining rocks are granite, often pegmatitic. and greenstone; these two rocks enclosing the gossan hill on three sides, southeast, northeast and northwest. Here we find a large ore deposit caught in a sharp angle where the gabbro pushes into the neighboring rock, as happens so often elsewhere.

The ores of the Blue lake region are like those of other parts of the district in most respects, though the pyrrhotite is apparently more magnetic than elsewhere. Masses of the ore near Blue lake are fairly strong natural magnets, readily attracting the compass needle and holding iron filings, but they are, of course, far surpasesd in this respect by magnetite. Some octahedra of pyrite are found in the pyrrhotite.

The string of small lakes mentioned above follows in a general way the basic edge of the nickel-bearing eruptive, as if that were most easily acted on by weather, and their western shores often consist of bluffs of reddish, syenitic-looking rock, the more acid and also more resistant phase of the eruptive.

Leaving the Whistle property going westward the contact is found forty paces north of the northwest corner post of lot 7 in the fourth concession of Norman. The ground succeeding is low and drift-covered for nearly a mile, with no outcrops of the basic edge till near the line between lots 9 and 10, where the contact shows with a test pit and gossan 210 paces south of the northwest corner post of lot 9 in the fourth concession. To the west this outcrop is followed to low ground again with gravel deposits, but the norite outcrops south of the northwest corner post of lot 10 in the fourth concession at 410 paces. On following the uncut line half a mile to the west between lots 11 and 12 north from the post at the south boundary of the fourth concession a small test pit in a body of ore was encountered at 1,940 paces. The Laurentian here contains good-sized bands of green hornblende schist like that which accompanies the Hutton magnetic ore deposits. The Laurentian was also found 1,010 paces north of where the boundary of Wisner and Norman crosses the Vermilion river in concession four.

The acid edge of the eruptive was traced southward through Norman and Capreol to the sand and gravel plains which hide the bed rock in Garson township; and the relationship of the eruptive to the overlying sediments was the same as has been described in other townships. A good exposure of the contact is seen on the road north from Dawson toward Moose mountain, where, as one advances, the tuff takes on the character of conglomerate, and then of boulder conglomerate with a felsitic

ground-mass before the edge of the eruptive is reached. In general, the ridges of tuff and conglomerate, as well as of the eruptive, run north and south at this eastern end of the range, evidently conforming here as everywhere else to the direction of the line of contact, showing a close relation between the dips and strikes of the overlying sediments and the line of outcrop of the basin-shaped eruptive sheet.

No ore deposits are known on the acid edge at this end of the nickel belt, but a so-called nickel mine was found not long ago at the east end of Onwatin lake in black slate. Two openings made here show only iron pyrites.

South of the Blue lake region the wide gravel plains referred to in the account of the northeast end of the southern nickel range intervene between the two ranges for about two miles, leaving the exact boundary at this point somewhat doubtful. On the map the boundaries have been connected in what seemed the most probable way.

The detailed account given in the foregoing pages, showing the continuity of the basic and acid edges of the nickel eruptive round the whole basin, and connecting up what were formerly spoken of as the main, or southern, range, and the northern range, make it clear that we have to do with a single sheet of eruptive rock, everywhere dipping inwards. This was originally buried under thick sedimentary rocks, but is now exposed all round the edge by their weathering and destruction, laying bare the eruptive sheet which had slowly cooled beneath them.

OTHER NORITE OR GABBRO MASSES

In addition to the great nickel-bearing laccolithic sheet which has just been described, there are numerous other outcrops of norite or gabbro, or of greenstone probably resulting from the alteration of gabbro, in the district, many of them having been mapped by Dr. Bell and colored in the same way as the nickel-eruptive. Most of these basic eruptive masses are elongated parallel to the strike of the adjoining rocks, which is in general parallel to the edge of the nickel-bearing eruptive, and in many cases small pockets of pyrrhotite and chalcopyrite occur in them, but always lower in nickel than the deposits of the main nickel range, and up to the present of no practical importance. The bands or bosses of gabbro in question are probably all later in age than the enclosing Huronian rocks; but there are also greenstones closely connected with much altered parts of the Huronian sediments, which seem to be of the same age.

What relation the isolated gabbro areas have to the nickel-bearing eurptive is uncertain, though they appear generally to be older than the nickel rock. Possibly they represent earlier eruptions from the same magma before differentiation had gone far, or possibly they are segregations from the magma of a medium acidity practically free from the sulphides. In many respects they differ greatly from the nickel eruptive, such as the lack of ore and of a differentiation into acid and basic phases on any large and regular scale. Until more time has been devoted to them their character in many points must remain doubtful.

Gabbros of the kind mentioned occur from Falconbridge township southwest to Nairn township, and locations for nickel have been taken up on many of them, but without important results up to the present. They are confined to the Huronian region south and southwest of the main nickel range, none being known from the Laurentian areas to the north and northwest or to the southeast.

To give an idea of these rocks the best known area, lying to the east and south of Sudbury will be described.

The Sudbury Gabbro Area

Just to the east of the town of Sudbury, beyond the creek, an irregular mass of hills cut by some ravines and embayments, rises to a height of over 200 feet, having an area of about four square miles, and sending a tongue five miles southeast along

the northwest shore of Kelly lake. The rock is gabbro, usually much weathered, and wherever the adjoining Huronian sediments are found in contact with it along the edges they are tilted up to the vertical or even slightly overturned, so that the eruptive is clearly later than the Huronian. On the west and north of the main area and along the northwest side of the Kelly lake extension the adjoining rock is well stratified graywacké with slaty layers; on the south so far as known the sediments are graywacké conglomerate later in age than the former rocks. The east side of the eruptive mass has not been studied in any detail.

The laccolithic relationship of this mass is pretty certain, but its form is very irregular, and there may really have been a succession of laccolithic flows instead of a single sustained irruption of magma into the sediments. While the whole mass was probably domed over with sedimentary rocks in the beginning, there are now very few remnants of them left except some stretches which rise well up on the flanks of the hills but do not reach the top.

Far the greater part of the rock is a greenish gray gabbro in which the pyroxenes have mostly weathered to hornblende, though one specimen proves to be norite, of a quite different kind from the norite of the nickel eruptive. It has not the dark color, the blue blebs of quartz, nor the mica which characterize the nickel range norite; it is never "pockmarked" with rusty holes from which ore has weathered, nor has it gossan or deposits of ore around the edge; though a few small outcrops of ore occur away from the edge. It shows no tendency to have one side acid and the other basic, though there are large acid segregations in many places on top of the range of hills near the centre. If the band is laccolithic, as it appears to be, and similar to the main range, the acid portion should be at the top, with gradations to a basic portion with ore at the bottom. The latter part may be hidden below the surface, and the acid segregations on the tops of the hills may correspond to the acid edge of the nickel eruptive, though very different from it in character.

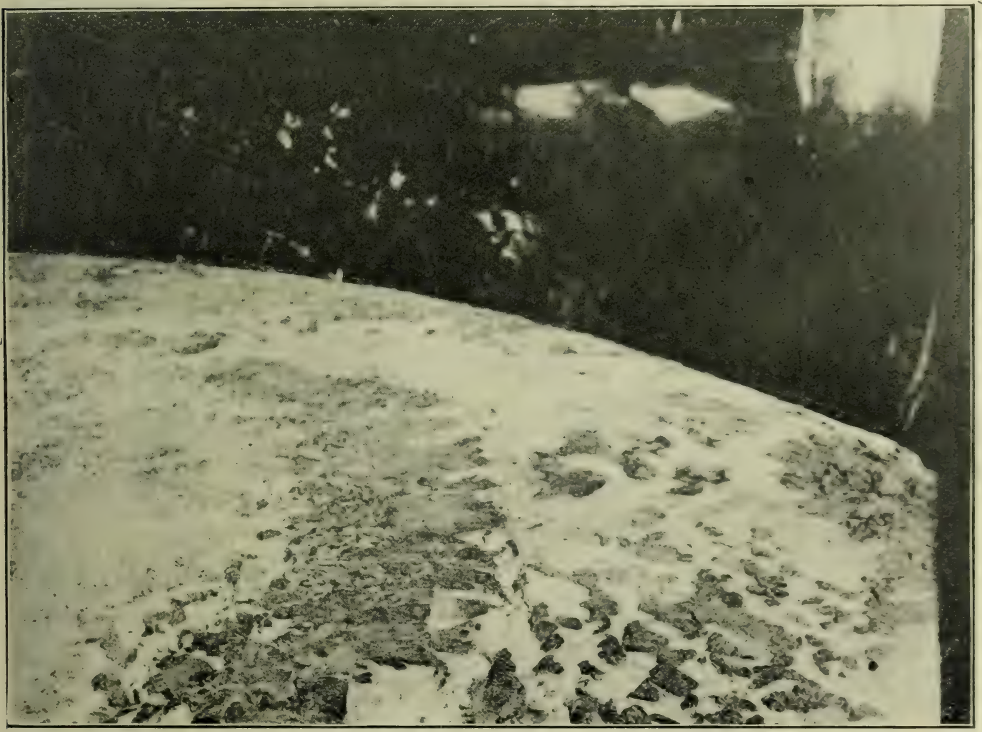
The acid segregations are very curious, sometimes having the look of gigantic concretions with a ring of green hornblende round the edge, followed by white plagioclase, which may become pegmatitic, and finally enclosing more or less quartz, the whole mass being from a few feet to 50 yards in diameter. The hornblende crystals are often several inches long, blade-like, and in cross section may have in the interior a negative crystal form filled with plagioclase or some other white mineral. Good examples of the segregations are found on various hill tops east of Sudbury and for half a mile or more along the top of the ridge near Kelly lake. In the latter region they follow a general direction along the centre of the range of hills, though the masses of white minerals are not connected. The largest known south of Copper Cliff is used as a source of quartz for converter linings, and already a great many tons of nearly pure quartz have been quarried from its centre, leaving the more felspathic portions as the walls of the pit, with an outer rim of hornblende, the line of mixture forming the rock sometimes called malchite.

It is possible that these areas of plagioclase and quartz represent masses of quartzite enclosed in the gabbro and completely re-crystallized, though there is no direct evidence of this. They seem to be analogous to the malchite masses with hornblende crystals, white plagioclase and some quartz along the edge of the main nickel range at Murray and Elsie mines; and the same cause must have produced them in each case. As the examples from Murray mine clearly have nothing to do with the acid edge of the eruptive, which is four miles away, we must conclude that the much larger row of white segregations in the Sudbury laccolith are probably not the equivalent of the acid phase of the nickel eruptive.

Beginning at the north end of the Sudbury laccolithic band where the rugged hill sinks northwards into a swamp followed by the creek in concession V of McKim, we find a rim of quartzite or graywacké with seams of slaty material running all along the flank of the hill and having a strike of 60° with nearly vertical dip. Passing to

the west and southwest the hill slope on the line between concessions IV and V shows quartzite or graywacké tilted round so as to have a strike of 100° with a dip of 80° to the north; but there has been great disturbance here, blocks of the sedimentary rock being carried off by the gabbro. Farther to the southwest the sediments lean against the gabbro in a more normal way, with a strike of 30° and steep dip beneath the eruptive; and just east of Sudbury the same relation is found, except that the dip is 70° or 80° to the east, i.e. under the laccolith, the eruptive growing finer grained against the quartzite.

A little to the south near the corner between lots 4 and 5, cons. III and IV, a wedge of the sedimentary rock runs a little north of east for nearly a quarter of a mile before it feathers out on top of the gabbro. Still to the south a valley runs into the hills in the same direction, perhaps weathered out of the sediments, though drift



Hill east of Sudbury ; concretionary structure in gabbro.

covers the solid rock. To the south of the valley the gabbro shows no rim of quartzite, and near the Canadian Pacific railway it seems nearly cut off from the long band running towards Kelly lake, quartzite being exposed considerably to the east, though not seen in contact with the eruptive.

The relations on the east side of the gabbro area have not been studied; on the south we find graywacké conglomerate later in age than the quartzite for the most part, but cut by the gabbro. Some strips of quartzite occur, however, north of Ramsay lake and the railway against the gabbro or upon its southward slope, one such strip only ten feet wide running for some distance in a direction of N. 25°. The contact with the graywacké conglomerate and patches of quartzite along the south side toward Ramsay lake is somewhat confused, blocks of the sedimentary rocks being enclosed in the gabbro for 100 or even 200 feet from the edge; and a band of conglomerate runs for nearly a mile, with very irregular boundaries, between the main mass

of gabbro and a narrow southern row of gabbro hills. As this has weathered faster than the eruptive, it has been made use of for the road between Sudbury and Wahnapitae.

The long band of gabbro running towards Kelly lake has relations to the quartzite much like those nearer Sudbury. The strike is about 60° or 70° and the sedimentary rocks rise along the northwestern flank of the hills as a fringe having with local variations the same strike, but being in many cases brecciated at the very edge. On the southeast of the ridge only the shore of Kelly lake has been studied, and here the gabbro runs beneath the water in most places, though quartzite or conglomerate occur at two points and are found against the edge farther northeast.

Ore occurs at two points at least in this band of gabbro, one east of Sudbury, the other half way between Sudbury and Copper Cliff. The Sudbury deposit occurs connected with one of the segregations of white plagioclase and quartz a little north of the water tank, where a small test pit shows rusty rock, copper pyrites and pyrrhotite with some quartz; but the amount of ore seems insignificant.

The other outcrop is on the north half of lot 6, con. II, McKim, near the middle of the gabbro band, where there is a considerable stretch of gossany surface containing a pocket of pyrrhotite with some copper pyrites, opened up by a test pit twenty feet long and five feet wide. Though larger than the other deposit, this too is of no economic importance so far as can be seen from the exposure. Another test pit is said to have been deep enough to require a ladder, but my guide was not able to show me it.

Since many strippings and small prospect pits have been opened on these outside gabbro bands with no valuable results up to the present, we must suppose either that the amount of magma in them was too small to provide a workable body of ore by segregation, or that the ore is at too great a depth to be visible on the surface.

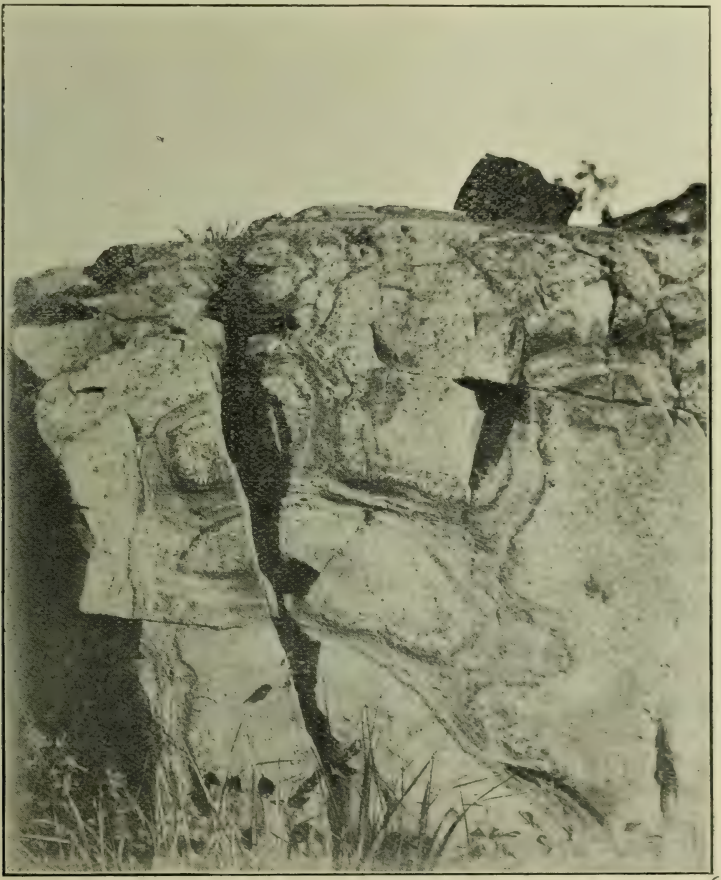
Smaller gabbro areas south of Ramsay lake and in the neighborhood of Nairn Centre have been taken up as nickel locations, and have been proved to contain some pyrrhotite, but the amount is too trifling and the grade of the ore too low to make them of value.

Older Norite and Greenstones

Along much of the southern nickel range and at a few points on the northern range an extraordinary mixture of green or gray rocks occurs, apparently having some relationship to the nickel-bearing eruptive. Though it has been referred to from point to point in the discussion of the basic edge of the main range, it should be briefly taken up as a whole. Much of this rock has been lava flows, as shown by the "pillow" and amygdaloidal structures frequently mentioned in previous parts of this report. The pillow structure is supposed to be due to dragging or rolling of still viscid lava; though it might be explained perhaps, in some cases at least, as formed of bombs. The pillows are of all sizes up to five or six feet in diameter, and show irregular rounded forms, apparently somewhat squeezed together, perhaps merely by their own weight. They are, however, separated by a narrow band of seemingly structureless green material, usually much finer-grained than the rock of the pillows themselves. The middle of the pillow is generally of dark or light gray fine-grained material, sometimes unchanged norite made of plagioclase and hypersthene, at others metamorphosed to a confused hornblendic rock. This merges into a speckled band containing many white spots suggesting amygdaloids, the spots being specially crowded against the edge, as if steam could expand near the outside of a still viscid mass of lava but was unable to do so in the middle, or as if the steam bubbles pushed in all directions toward the outside, but could not escape through a cold outer film.

The fine-grained green band which separates the pillows thickens to fill the spaces at some points, but at others there are white and green strips developed in the wider spaces with hornblende crystals, etc. Is this intermediate material ash?

The great mass of the older norite is, however, not pillow-like nor amygdaloidal, probably because these structures are confined to the surface of lava flows. No distinct lava sheets or flows have been distinguished, the varieties of rock mentioned seeming to be inextricably mixed through the large amount of faulting and brecciation which the region has undergone. In most cases the older norite is largely changed to hornblendic rocks, and almost all the surfaces even of the freshest norite are crossed by numerous bands of darker green, consisting chiefly of hornblende, where fissures permitted water to percolate so as to produce a variety of change going on at considerable depths, often confounded with weathering. These bands widen and become more numerous, until finally the rock has changed to greenstone or hornblende porphyrite.



Pillow structure in older norite, near Elsie.

In many examples the general rock is older norite with large rhomboidal crystals of hornblende, often surrounded by a narrow white rim, scattered through it. On weathered surfaces these crystals and the hornblende seams stand out a quarter or half an inch above the rest.

The older norite is closely associated with singular green schists or greenstones filled with white pea or bean-like spots of quartz, which may be a variety of the lavas or a greatly metamorphosed sediment. All grades in size and complexity are found between the tiny, homogeneous ''peas'' and concretions two inches in diameter with dark hornblendic centres and white borders. Beside these doubtful rocks there are

also some undoubted sediments, graywacké of a quartzitic kind, enclosed in the complex of the greenstones and older norite too intimately mixed with them to be separated in mapping.

This group of rocks is of a very resistant nature and commonly stands up along the low basic edge of the southern nickel range, as rugged hills, sometimes in a narrow belt but occasionally a mile in width.

DISTRIBUTION OF OLDER NORITE AND GREENSTONE

The older norite is easily distinguished from the norite of the basic edge of the nickel-bearing eruptive, being much finer-grained and more basic in character, but it is very difficult and often impossible to separate it from the greenstone into which it is transformed by the development of hornblende in place of the pyroxenes. Where any of the unchanged norite remains there is no difficulty in mapping it along with

Weathering of Norite, Manitoulin and North Shore Ry.

the products of its alteration; but where all trace of the norite and of the pillow and amygdaloidal structures have vanished, it becomes doubtful whether the rock should be classed with the older norite or not, since there are numerous bands of greenstone and hornblende porphyrite with considerable quartz in their constitution that probably have no relation to an original norite.

In this account of the distribution only greenstone found connected with norite or with pillow lava will be considered to belong to the series. They have been traced with some care along the nickel range, but have not always been mapped to the south, so that the width of the band is often uncertain; and they have not been looked for at all at a distance from the nickel range, so that other areas may exist in the district not distinguished from the common greenstones and green schists.

Beginning at the west end of the nickel range, there are fine-grained noritic rocks mixed with various greenstones as if the matrix of a crush conglomerate at the Sultana

mine, but it is doubtful if the hill should be classed with the older norite since the typical structures have not been observed; and the same may be said of greenstones occurring at the Chicago and Victoria mines as well as the Vermilion.

We come to undoubted older norite first in the vicinity of the Gertrude mine in the southeast corner of Creighton township, where this rock mixed with greenstone runs from west of the compressor plant to a point near the railway station, a distance of one-third of a mile, with a breadth of several hundred yards. Whether the greenstone which extends widely to the south belongs to it is uncertain, and the greenstones along the Manitoulin and North Shore railway to the east also are doubtful; but just to the east of the Gertrude proeprty, where the margin of the basic edge bends northward there is a half mile of greenstone mixed with older norite to the north of the railway.

At Creighton granitoid gneiss cuts out almost the whole of the greenstone series, and no older norite has been found between this and North Star, where a small strip lies just south of the nickel range. The rock is chiefly granitoid gneiss and granite with little greenstone, between North Star and the great Copper Cliff offset, and none of the older norite has been observed to the west of it.

Just east of No. 2 mine at Copper Cliff a range of greenstone hills begins and extends northward with some irregularities, but scarcely any interruption, to Elsie and Murray mines, a distance of more than two miles, with a breadth of half a mile on the average. Much of this area is typical older norite or shows pillow structure, so that there is no doubt of its position in general; but there are considerable patches of sediments, quartzite or graywacké, enclosed in it, and the younger granite comes between it and the nickel range where the offset joins the main range.

Near Murray mine a large mass of granite cuts off the greenstone and associated rocks, running between the Frood-Stobie offset and the main range, but immediately north of Stobie the older norite and greenstone in a typical form rise as rugged hills and extend to the Little Stobie, Mt. Nickel and Blezard mines with a length of a mile and breadth in places of more than half a mile.

Beyond this toward the northeast the country is largely covered with swamp or drift deposits along the margin of the nickel range, and not much detailed mapping has been done, but greenstones are known to occur at many points along the range, and the pillow structure has been found near Kirkwood mine in Garson township.

Along the northern nickel range the older norite and pillow lava have been observed only at one point, north of Joe's lake in Wisner township, but no special search has been made for them elsewhere. However, there is on the whole much less likelihood of its occurring there than near the southern range, since the granitoid gneiss of the Laurentian makes the usual country rock with comparatively little greenstone of any description.

There is plenty of greenstone to the east of the nickel range near Blue lake and points to the north, but the older norite has not yet been observed there, perhaps because it has not been particularly looked for. Pillow structure was seen at one point near Blue lake, however.

To sum matters up, the older (or micro-) norite is known to extend, with some interruptions from granite or granitoid gneiss, from Gertrude to Blezard mine, a distance of about 14 miles, with a greatest width of about half a mile. An outcrop has been found near Kirkwood mine, about three miles northeast of the Blezard mine, so that the total length is 17 miles. It is not known to occur anywhere in the district at a distance from the nickel range, but always at or near the margin of the nickel-bearing norite. It is highly probable that the lava flows, etc., of the older norite series represent an earlier outbreak of material from the same general magma as supplied the nickel eruptive, but at a very much earlier date, in fact before the sediments of the interior basin were laid down. If this supposition is correct there

were surface outflows of lava of a basic type, followed by a long period of quiescence during which the 10,000 feet of sediments were deposited. A second period of activity resulted in spreading the great laccolithic sheet beneath the sediments and over the older norite, the magma as a whole being this time of medium basicity. Finally, an acid remnant of the magma may have been erupted forming the later granite which cuts both the older and the later norite, though this is uncertain.

Granites Near the Nickel Range

Several elongated areas of granite or syenite or gneissoid varieties of these rocks occur along the southern nickel range as if they had some connection with it, though the gneissoid rocks have generally been thought to be Laurentian. They differ considerably from the grayish medium-grained gneisses of the Laurentian to the east and north of the nickel eruptive, and are perhaps all later in age.

Later granite, Manitoulin and North Shore Ry.

In type these rocks are variable. running from flesh-colored to gray, from fine-grained to coarse, from porphyritic to non-porphyritic, and having all degrees of gneissoid structure. They are always later in age than certain greenstones of which they enclose fragments and than the graywackés, quartzites and slates of the Huronian. The variety referred to as porphyritic granitoid gneiss is generally older than the norite, which grows finer-grained against it; but there are doubtful contacts, and Dr. Barlow may be right in assigning it to nearly the same age as the nickel eruptive.[28] There are also reddish medium to fine-grained granites which are distinctly later than the nickel eruptive, since they frequently send apophysae into it and penetrate it, sometimes as long dikes. How these granites are related to the porphyritic granitoid gneiss is uncertain, but they appear to be a good deal younger, as a whole, perhaps

[28] Geol. Sur. Can., 1904, Part H, pp. 53-4.

later outflows from the same magma. It seems as if granitic eruptions were very long continued in the region, for not only have we the older granitoid rocks against which the norite cooled, but masses and dikes of granite up to the very end of the series of eruptions, for two small dikes have been found cutting the diabases which penetrate all the other rocks of the region. As these acid rocks have erupted at various times all along the scale without showing much difference in composition, we should perhaps look on them as separate in origin from the magma of the nickel eruptive, though from a neighboring source.

DISTRIBUTION OF GRANITES

A large band of granite and granitoid geniss with some greenstones intermixed begins about three miles east of Victoria mine and runs east across Vermilion river to the northeast corner of Graham township, where it bends to the northeast and widens from a mile or a mile and a half to two miles or more as it approaches Creighton. It forms the country rock of the norite for two or three miles, but near Gertrude is separated from it by greenstone and older norite. The boundary between greenstone and granite is hard to fix in this region, the two being mixed. At Creighton it once more touches the basic edge and continues in this relationship to Copper Cliff. The hill south of Creighton shows an extraordinary confusion of coarse granitoid gneiss with inclusions of finer gneiss, arkose and porphyrite, the whole greatly faulted and crushed into conglomerate. Some of the gneiss has light and dark bands like the Laurentian.

Between Creighton and North Star different phases of granite and granitoid gneiss with some greenstone are well exposed in the rock cuts of the Manitoulin and North Shore railway, some parts with large flesh-colored porphyritic crystals in a darker ground being very handsome and worthy of mention as ornamental stones.

Near Elsie junction the coarse porphyritic rock is replaced by a small area of rather fine-grained bright red granite which forms two or three hills in the greenstone series, but the fine-grained granite has not been found in contact with the coarser rock so as to compare their age.

To the west of Copper Cliff coarse gneiss rises as steep hills and encloses in part the offset of norite as far as No. 2 mine, the norite being finer-grained at the margin. Small dikes of finer-grained granite penetrate the norite, however, as though later in age, so that two eruptions of granite are represented here.

The band of granite described is about 12 miles long and runs roughly parallel to the nickel range and to the strike of the Huronian. It is not, however, a single eruptive band or sheet, but includes rocks of quite different ages, one cutting the other in some cases, and in almost all parts there are older greenstones included, sometimes to such an extent that sharp mapping of the boundary between the granite and greenstone is impossible, the latter rock increasing more and more until it becomes more important than the granite.

To the southeast of Murray mine a range of pale flesh-colored granite hills rises along the Canadian Pacific railway and runs northeast near the nickel range to a point near Little Stobie mine, greenstone, graywacké and various schists lying along its southeast border. This granite touches the norite at Murray mine, and is distinctly younger than it, since it sends projections into it. The boundary of the granite with the greenstones is often a very brecciated one, blocks of the dark rock being enclosed in a matrix of granite which ramifies between the masses. Somewhat similar granite occurs as irregular bands near the middle of the norite at various points to the west and northwest, as well as towards Whitson lake, and it is probable that all have had the same origin. Diamond drill cores show rock of the same kind fom 900 feet depth below the surface of the norite about the middle of lot 8, con. II, in Blezard township.

Bosses of paler gray granite, perhaps of different age, appear in the graywackés and quartzites near the northwest corner of McKim township; and small areas are found in other parts of the region to the south and east of the nickel range, but they have not been studied in detail.

Huronian Greenstones

In the sketch of the character and distribution of the eruptives of the Sudbury district just given only the more important types have been referred to, the nickel eruptive, the Sudbury laccolith, the older norite and asosciated greenstone, and the granitic rocks. There are, however, many bands or bosses of a peculiar hornblende porphyrite with coarse crowded crystals occurring in various places in the sedimentary rocks, probably older than any of the eruptives that have been taken up. Examples of these are found running as a succesion of small lenticular patches for about two miles parallel to the Flood-Stobie offset, and many other outcrops of the same nature have ben noted in McKim, the only township studied in detail apart from the nickel range. It is likely also that the bands and irregular areas of greenstone, partly porphyritic and partly without phenocrysts, between the Blue lake face of the nickel eruptive and lake Wahnapitae belong to the same category. They are older than both the norite and the granite, the latter having carried off great strips and masses of them, and are of the same character as the greenstones enclosed in the Laurentian to the west and north of the nickel range.

Diabase Dikes

At the other extreme from the very ancient basic eruptives just mentioned, which are so far altered that their constituent minerals and in most cases even their original

Weathering of diabase, west of Sudbury.

structures have been lost, we have comparatively modern and usually very fresh basic rocks in the diabase dikes which intersect all the rocks of the district. The rock varies from fine-grained or compact to coarse-grained in the middle of large dikes, and in many cases it is highly porphyritic, flat plates of plagioclase sometimes two inches in longest diameter being embedded in a fine-grained ground. The color is gray, weathering brown, and the rock is specially apt to form spherical shells and boulder-like masses on exposed surfaces. Thin sections show that the rock is an admirably fresh olivine diabase.

The dikes are of every dimension from paper thinness to 100 yards in width, and they may have a length of several miles. In almost every part of the region which has ben carefully studied south of the main nickel range, these dikes have been found, and they appear to be particularly numerous in the neighborhood of the mines, perhaps, however, merely because those parts have been the most minutely studied. There are few rock dumps at the mines where the diabase is not to be found, and often the dikes cut ore, country rock and norite in various directions. These dikes are specially numerous and interesting at Creighton and Murray mines, where they cut the ore bodies and have been chilled against the sulphides because of their better conductivity, so that a glassy edge has resulted, while the contact against the rock is very fine-grained but not glassy. At Creighton mine the great open pit shows dikes running 20° 15° and 35° west of north respectively, and two dikes meet on the north side of the ore body, while another dike, on the southeast wall of the pit bends round so as to become nearly horizontal. A curious feature of these dikes is the well-rounded boulder-like projections from them enclosed in the cre. These pseudo-boulders are coarser grained in the middle and compact or glassy in contact with the ore.

The great dikes near Murray mine having a strike of 125° or 130° have been mapped by Dr. Barlow, who has followed them from the mine to Ramsay lake beyond Sudbury, a distance of six miles.

Near Worthington mine also dikes are numerous, and a short distance to the northeast near Totten mine an irregular hill of diabase crosses the narrow band of norite. Large dikes are known also at Copper Cliff; in the laccolithic band of norite near Evans mine; north of Chelmsford in the sandstones of the upper sedimentary series; in the tuff near Joe's lake and the Vermilion river, at the northeast of the nickel basin; and near the Blue lake ore deposits; as well as at numerous other points which need not be detailed. No dikes have been reported, however, from the Laurentian to the west and north of the northern nickel range, but this may simply be because that formation has attracted less attention than the others. The majority of the known dikes are in or near the southern nickel range, which seems to point to some connection between them and the ore masses. They have nowhere affected the ore bodies, however, beyond filling fissures in them; and they clearly belong to a much later set of phenomena than those connected with the coming into place of the nickel-bearing sheet and its accompanying ores. It may be, however, that the great number of fissures filled by the diabase dikes resulted in part at least from shrinkage due to the cooling of the nickel eruptive and the rocks which were heated at its contact.

It is noteworthy that the directions of the dikes show no relationship to the northeast and southwest strike of all the other rocks in the region, which usually have a more or less perfect cleavage or schistosity parallel to the nickel ranges; showing that the compressive force due to the settling of the foundations after the nickel-bearing magma had risen and spread out where we now find it, was then at an end.

Eruptives Compared as to Bulk

If we omit the "basal complex" of eruptives, mainly gneiss but with some unfoliated granite also, as well as considerable patches of greenstone, the nickel-bearing eruptive sheet far outweighs all the other igneous rocks of the region with its estimated bulk of 600 cubic miles. In average composition it comes near to the mean of eruptive rocks tne world over, the percentages working out as follows:

	Per cent.
$Si\ O_2$	62.172
$Al_2\ O_3$	14.661
$Fe_2\ O_3$	1.112
$Fe\ O$	6.753
$Mg\ O$	2.489
$Ca\ O$	4.368
$Na_2\ O$	3.417
$K_2\ O$	2.299
$H_2\ O$	1.213
$Ti\ O_2$	0.712
$P_2\ O_5$	0.177
$Mn\ O$	0.10
$Ni\ O$	Trace
S	Trace

The eruptives most immediately associated with it are the "older norite" and related greenstones, and the finer-grained granites which lie parallel to it or form dikes in the eruptive sheet; and it is possible that these rocks are derivatives from the original magma, the older norite having been separated and erupted before the main sheet, and the granites after it. The porphyritic granitoid gneiss of the region has probably no direct connection with the hearth of the nickel eruptive.

In volume the older norite and the later granite are insignificant when compared with the great laccolithic sheet, each containing only a few cubic miles so far as known.

However, there is in the region another mass of materials of eruptive origin, the thick sheet of pyroclastic sediments called the Onaping tuff, including a number of cubic miles of volcanic debris, which must have come from some source not far off, possibly at the time of the surface flows of the older norite. That the tuff is older than the norite-pegmatite sheet underlying it has been shown in a previous chapter. An analysis by Prof. Walker gives this rock a composition somewhat more basic than the average of the nickel eruptive, but not so basic as the norite at its outer edge. There are, however, fragments of quartzite in the tuff which would increase the silica, and on the whole the rock seems quite different from either the nickel-bearing eruptive or the older norite, more basic than the former and much less basic than the latter.

THE HURONIAN SEDIMENTS

The sedimentary rocks of the Sudbury district underlying the nickel-bearing sheet are undoubtedly older than those overlying it, and have generally been considered to belong to the Upper Huronian as hitherto defined in Canada equivalent to the Lower Huronian according to the latest classification. Their relationships have never been worked out in detail, since they contain no economic minerals to give them special importance, and are exceedingly complex in their structure. As Dr. Barlow well says, "In the first place all the rocks of the district have been greatly disturbed, so that the originally horizontal strata are now tilted at very high angles, in some cases having assumed a vertical attitude, and occasionally have even been overturned as a result of the mechanical stresses to which they have been subjected. In some cases and over extended areas the rocks have been so metamorphosed that the planes of original sedimentation are more or less completely masked or even destroyed altogether." In addition Dr. Barlow calls attention to the schistose structure and cleavage crossing the bedding planes and the intrusion of eruptive masses through them disturbing the original order of deposition.[29] To the difficulties shown in the above quotation may be added the fact that faulting has taken place extensively all over the region, resulting in crush conglomerates and breccias which still further confuse the relationships.

The history of these sedimentary rocks is far from easy to unravel, but certain facts stand out clearly. They are distinctly water formed sediments, and in my opinion mainly ordinary clastics, sands and clays, and not to any large extent pyroclastics. They must have been once approximately horizontal, but they were greatly disturbed during the elevation of the Laurentian mountains, whose truncated bases touch them at various points, being thrown into close folds between the Laurentian areas; and perhaps before that time they had been domed up over laccolithic eruptions of norite older than the main eruptive sheet, and perhaps also by bosses or batholiths of porphyritic granitoid gneiss of a different age from the Laurentian. Then came the vast disturbances before and during the formation of the nickel-bearing laccolithic sheet, beginning at a remote time with surface lava flows and the raining down of a great thickness of tuff; followed by the spread of 600 cubic miles of magma between the older rocks under consideration and the later sediments. This climax of

[29] G. S. C. Vol. XIV, Part H, p. 62.

Plant for treating Cobalt ore, Copper Cliff.

Hospital at Copper Cliff.

the eruptive operations was accompanied by immense faulting and settling of the older rocks through the removal of molten material from beneath and the spreading out of the laccolithic sheet above them. With the settling of the sheet into a synclinal form came the lateral pressure which developed slaty cleavage and schistose structure parallel to the curved axis of depression under the syncline. Finally there was settling and shrinkage due to the cooling of the great eruptive sheet, causing many faults and fissures into which diabase could ascend.

When this complex history is kept in mind the difficulties of the stratigraphy are not surprising.

As probably the oldest of the sediments the gray or greenish or flesh-colored rocks variously called graywacké, quartzite and sometimes arkose may be taken up first. In some places these rocks show little or no hint of stratification and have been so far reconstructed as to look like fine-grained gneiss or granite or syenite, for which they have at times been taken; but the lowest part consisting of interbedded coarse and fine materials often shows well developed stratification on weathered surfaces. As suggested by Dr. Barlow, these darker rocks are bent into a syncline enclosing flesh-colored arkose.

Graywacke

As the oldest rocks of the region it is intended to describe first a series of well stratified rocks ranging from quartzite to slate, usually including a good deal of decayed feldspar and fine-grained dirty-looking materials as well as angular or rounded fragments of quartz and a chloritic or sericitic substance. In many cases the rock is very distinctly banded, coarser quartzose bands standing out while finer slaty bands with less quartz have weathered down as parallel furrows. These rocks have usually not been so greatly re-crystallized as the overlying arkoses, though there are phases looking like gneiss or mica schist; and this fact with their characteristic appearance of stratified sediments gives one the impression that they are younger than the felsitic-looking arkoses. There are, however, transitions between the two rocks and they probably represent a continuous succession, the graywacké being the older of the two.

The graywackés as here defined have well-marked bedding and sometimes cross-bedding and other structures characteristic of wave action; and rather rarely, rounded pebbles of various kinds of rock are found interbedded with the finer materials. They cover much more space than the arkose and present much more variety.

In the southwestern part of the district rocks of this kind show as hills and ridges near Worthington and Victoria mine, accompanied by thick bands of slate and also of quartzite as extreme phases, and one band of quartzite is pure enough to be worked as material for the lining of converters at Victoria mine,[30] containing 90 per cent. of silica.

Some of the more slaty bands are impregnated with sulphides and have rusty surfaces which have attracted prospectors, but they contain only traces of nickel or copper. The strike is generally about east and west, parallel to the basic edge of the nickel eruptive, and near Worthington a dip of 708 to the south has been recorded. Green schist and greenstone are often interbedded with the slaty graywacké.

Near the church at Victoria mine a common phase of the graywacké is well illustrated, showing an ice-planed surface of pale gray color slightly banded with darker gray, and in parts covered with markings half an inch long, oval depressions with a narrow ridge in the middle, probably pseudomorphs after staurolite. Small stretches of fairly well stratified graywacké occur near Gertrude mine. Graywacké is widely distributed near Copper Cliff and Sudbury also, with much the same features as near Victoria mine. At Copper Cliff it is largely buried under the clay flats, but numerous small hills rise above the drift, and narrow bands skirt the flanks of harder rocks,

[30] Hixon, Eng. Min. Jour., Dec. 29, 1904, p. 1022.

such as the arkose west of the village and the laccolithic range of hills near Kelly lake. The strike has here changed to N. 40° to 75° E., parallel to the general structures of the rocks of the region, and the dip varies from 65° to verticality. In the village of Copper Cliff the graywacké contains some patches of conglomerate which may be of beach formation. The hills to the northeast of the village and in the neighborhood of Clara Bell junction are largely graywacké, some parts near the latter point containing sulphides enough to weather very rusty. To the southeast of the range of arkose hills which occupies the centre of the syncline the graywacké with very pronounced bedding occupies the lower ground and apparently extends from this east almost to Ramsay lake, being cut off in that direction by a band of gabbro. Very good exposures are found between miles 2 and 3 of the Manitoulin and North Shore railway, and east of the C. P. R. station at Sudbury, the peculiar spotted variety formerly called "rice rock" occurring along the C. P. R.

Perhaps the most typical exposure of these rocks is to the north of Sudbury on a steep hill which dominates the town. Here the stratification is very distinct, and various interesting structures occur, cross bedding on a small scale and wavy projections of a quartzitic variety into slaty bands. The road north towards Stobie gives fine exposures of the same rock, which ends, however, before Stobie is reached, being cut off by greenstone. In this part the strike ranges from 30° to 80° and the dip is not far from vertical. The graywacké extends to the east also along the valley of Sudbury creek between the gabbro of the laccolith east of the town and the hills to the north, but it is cut by dikes or bosses of hornblende porphyrite and by a boss of granite just within Neelon township. To the north of McKim stratification is not evident in many places and as there is little of the slaty material, the hills in this direction should perhaps be called quartzite or arkose, though without the pale flesh color usual in these rocks elsewhere in the district. Where the strike is visible it trends about east and west. West of this toward Stobie a mass of gray quartz porphyry is almost indistinguishable from the quartzite enclosing it.

The most singular phases of the graywacké run for about 5 miles northeast and southwest from near Copper Cliff almost to Stobie mine, parallel to the edge of the nickel range but some distance to the southeast. Here the graywacké has been more thoroughly re-crystallized than in most places and has the appearance often of sericitic or chloritic schist or even of fine-grained gneiss. Along most parts of the band of altered graywacké, which is not more than a quarter of a mile wide at greatest, there are numbers of pseudomorphs after staurolite, which may even reach 5 or 6 inches in length. The elongated six-sided cross-sections and occasional twins of the St. Andrew's cross type make the original nature of the mineral clear, though the crystals are now completely changed to quartz in minute grains or a pale green scaly mineral like talc or sericite. As the pseudomorphs are commonly paler than the rock, or even white, the appearance is very striking. In some parts the crystals are crowded in bands with spaces containing few crystals between them, the strike of the bands differing from that of the schistosity; in one case the crystals run 110 while the cleavage is 60°, and in another the two directions are 90° and 45°. It is likely that the stratification is indicated by the bands of crystals, the original beds having differed in composition.

Close beside this very schistose variety there is a curious rock showing less change, but containing the "eyes and eyebrows" of fine-grained quartz which have been noted before; and there are parts with smaller whitish spots of quartz not unlike those described previously in certain hornblende schists.

The presence of later granite near by and the fact that the Frood-Stobie norite offset runs through or beside this band of graywacké probably furnishes an explanation of their altered condition.

From point to point a very narrow and broken strip of typical water-formed conglomerate runs near the altered graywacké from Frood to the hills beyond Stobie toward the

Canadian Copper Company's new smelter, looking west.

Canadian Copper Company's new smelter in process of construction, showing Bessemer converters.

northeast. This was probably once a continuous stratum but is now pinched and faulted into short separate strips, two of which occur in the village of Stobie and just east of the mine. As the conglomerate contains large pebbles of granite, quartzite, greenstone, green schist, etc., it is evident that it indicates a break in the succession, but whether this is a basal conglomerate at the bottom of the Huronian or is of minor importance in the series of sediments has not been determined. The thickness of the conglomerate as exposed near Stobie is never over twenty feet, so that in magnitude it cannot be compared with the great beds of basal conglomerate found in the typical Huronian region or at Michipicoten.

Arkose

Between two irregular bands of the graywacké described above, sometimes sharply separated from the lower rock, sometimes passing gradually into it, is a range of rugged pale gray or flesh-colored hills consisting of arkose, beginning near Copper Cliff and ending near Stobie mine. The hills are not continuous but in a general way run through the centre of the graywacké as if enclosed in a syncline of the latter rock, though there is so much faulting and irregularity in the relations of the two rocks as to make the matter somewhat doubtful. The arkose is so much harder, owing to re-crystallization, that it resists the weather better than the graywacké, the latter often forming the low ground beside the range of arkose hills.

Just west of Copper Cliff one such hill stands up from the clay plain with a fringe of graywacké just to the east along its flank. No distinct stratification was observed in the arkose though the graywacké close by is well stratified. The next outcrop is a small sharp hill just east of the Copper Cliff rock house, sometimes spoken of as syenite; though the rock is so fine-grained as to suggest felsite. To the north this rock becomes mingled with blocks cf stratified graywacké as if it were an eruptive, so that the usual term is not to be wondered at. Dr. Barlow maps it as "regenerated granite" (re-crystallized quartzite). Mixed with green schists, graywacké and a little conglomerate, and more or less covered with stratified clay, the quartzite band extends to the eastward, growing wider to the west of Sudbury, where the two railways cross it giving excellent sections. On the Manitoulin and North Shore railway two miles west of the town the arkose has the look of fine-grained gneiss and is often sheared and crushed into a conglcmerate. Farther north along the Canadian Pacific railway the re-crystallization has gone even farther in places, and boulder-like patches in the rock are filled with hornblende crystals.[31] This range of hills, which is in places half a mile wide, continues northeast beyond the C. P. R., but dies out before reaching the Frood mine. though patches of the same rock are seen between Stobie and Blezard mines. Many smaller strips and patches of similar arkose are found in the band of mixed greenstone and graywacké lying to the northwest of this range of hills, and the contact of the two rocks is often brecciated, as if it had been a zone of weakness where faulting was specially active.

Arkose occurs on a still larger scale but of the same general character east of the Sudbury district along the south shore of lake Wahnapitae and at other points.

Beside the more prevalent pale gray or flesh-colored rocks which contain a large amount of feldspar, and so have been called arkose in the description above, there are true white quartzites in the region consisting almost wholly of quartz grains more or less cemented with silica; but these occur only in small outcrops and do not require special description. The best localities are a small hill south of the railway between Frood and Stobie, and the north shore of Ramsay lake east of the boat houses. These quartzites are closely like the widespread white quartzite of the typical Huronian region near Echo lake, etc. The hill of schistose quartzite west of Headquarters in Garson township belongs to the same class.

[31] Barlow, Ibid, p. 65.

Slate

Thin layers of slaty material occur at many points interstratified with the graywacké, but in some places there are thick beds of slate, quite free from coarser layers, so that they may be referred to as an independent formation. Beginning at the southwest, slate is found about half a mile west of Worthington station, the cleavage running 84° and the dip being 80° to the south. The rock is pale gray and somewhat lustrous and has a very perfect cleavage. A mile east of Worthington also gray slate is found in railway cuttings with the slaty cleavage cutting the stratification at a sharp angle; and slaty bands of considerable width, sometimes rusty from the weathering of pyrites, occur north of Victoria mine village. Slate occurs between Whitefish station and the band of granite south of the nickel range, and evidently has a considerable development in an east and west direction, since it is found at the falls of Vermilion river about two miles east of Whitefish where the Sault branch of the Canadian Pacific crosses the river. Here the stratification is well marked with a strike of 80°, while the slaty cleavage runs 50° with a dip of 85° to the southeast.

Slate and phyllite which probably correspond to those of the Victoria mines region are found to the west near Massey and Webbwood outside the boundaries of the district. The slaty rocks just described are always much more crystalline through the devlopment of sericite or chlorite than the black slate of the Onwatin formation belonging to the sedimentary series above the nickel-bearing eruptive.

Middle Huronian (?) Graywacke Conglomerate

All of the sedimentary rocks so far described belong probably to the Lower Huronian, adopting the terms agreed upon by the international committee on the classification of the Pre-Cambrian, but there is graywacké conglomerate in the region of a quite different character from the graywacké interbedded with slaty layers hitherto mentioned. The best exposure of the graywacké conglomerate is on the north shore of Ramsay lake between the lake and the Sudbury laccolithic band of old norite. The matrix of the conglomerate is dark gray and massive-looking, containing many small fragments of quartz and a variable proportion of boulders and pebbles, the latter being usually rather sparsely scattered. The larger boulders are commonly of granite, but there are some also of quartzite, and many small ones of white quartz. Near a small lake between Ramsay lake and the hill to the north there are large fragments of the stratified graywacké enclosed in this rock, which hardly shows any trace of stratification; but there has been so much faulting and crushing in the region that the blocks of supposed older rock may have reached their place by those means and not by process of sedimentation. At a small point on the north shore of Ramsay lake there are suggestions of a basal conglomerate overturned, so that the older rock is now uppermost, and the crowded granite boulders of the younger one are beneath it, but here again there is some doubt as to the relation of the two rocks. We may assume however that the inclusion of numerous quartzite pebbles, often of pale flesh color, implies a later age than the Lower Huronian, which so far as we know is the only source of these pebbles.

In our own work only this small area, two or three miles in length by half a mile in breadth, is known to belong to the graywacké conglomerate, but very similar rocks occur on a large scale near Kokogaming lake east of Wahnapitae and in other parts of the Huronian.

UPPER HURONIAN OR ANIMIKIE SEDIMENTS

The series of sedimentary rocks, referred to earlier in this work as the Trout lake conglomerate, the Onaping tuff, the Onwatin slate, and the Chelmsford sandstone, resting on the basin-shaped sheet of the nickel-bearing eruptive, are probably of Animikie age or according to the latest classification, Upper Huronian. There is little doubt that before the eruption of the laccolithic sheet these sediments were nearly

horizontal and rested on the folded and truncated edges of the Huronian and Laurentian rocks below, though few undoubted pebbles of any other Huronian rock than quartzite have yet been recognized in them. The common granite boulders and pebbles of the basal conglomerate may well have come from the Laurentian, though they may include other granites also.

Trout Lake Conglomerate

The rock immediately overlying the acid or upper surface of the eruptive sheet is always a conglomerate, often very coarse, containing pebbles and boulders of granite, quartzite, etc., clearly an ordinary basal conglomerate. This passes up into quartzite or cherty rock, often brecciated, and sometimes into a dark gray rock, which may be called graywacké, all containing some pebbles like those of the conglomerate. The width of the basal conglomerate varies from a few feet to more than 2,000 feet, and at 30° dip, the average thickness of the conglomerate and associated aqueo-clastic sediments has been worked out at about 450 feet.

The base of the conglomerate is always powerfully metamorphosed, often to such a degree that the boundary of the acid eruptive is hard to trace. The matrix of the conglomerate is changed into felsitic-looking material very like the finer-grained parts of the micropegmatitic granite, and the pebbles or boulders enclosed in it have very vague edges, though one can usually distinguish them as coarser textured spots, and thus decide that the rock is really conglomerate. In many places along the southeastern margin the rock has been squeezed or sheared into schist conglomerate with the pebbles greatly flattened and a matrix often like mica or chlorite schist. The finer-grained sediments above the conglomerate proper have been much less changed, but still show signs of silicification, rendering them often very resistant.

In the detailed account of the nickel-bearing eruptive the acid edge has been described as always in contact with the Trout lake conglomerate, which it has penetrated more or less from beneath and greatly metamorphosed. In that connection the distribution of the conglomerate has been referred to, so that it is not necessary to recapitulate the points at which it is found. It will be sufficient to say that next to the acid edge round the whole inner rim of the nickel eruptive the conglomerate is known to exist as a band varying from a few feet to more than half a mile (south of Gordon lake) with an average of about 1,000 to 1,500 feet. Good exposures are met between Vermilion river and Gordon lake, south of Windy lake, on the north shore of Whitewater lake, south of Trout and Joe's lakes and near Garson lake. The band is unusually narrow north of Whitson lake. It is noteworthy how often the line of contact between the acid edge and the conglomerate crosses lakes, the very accentuated topography favoring the formation of lake basins.

Onaping Tuff

Resting on the water-formed sediments of the Trout lake formation, and with transitions between them, is the Onaping tuff, a thick sheet of pyroclastic sediments mingled with varying amounts of pebbles or boulders of granite, quartzite and chert. The volcanic ash and lapilli are angular and now consist largely of serpentine and chalcedony. No clear evidence of stratification has been found in this series of rocks, which range from hard, almost flinty materials standing up as sharp hills, to soft slaty forms verging towards the true slate of the next formation. It may be that the flinty variety, which lies immediately upon the Trout lake rocks, has been solidified with silica brought by circulating water from the acid eruptive; while the upper part not being thus consolidated has yielded to pressure and taken on the slaty cleavage.

The thickness of the tuff is hard to determine sharply because of its blending upwards into the Onwatin slate, but assuming the boundary to be the low hills facing the valley occupied by the slate proper, we find an average thickness of 3,800 feet.

Much of what has been said of the distribution of the conglomerate will apply also to the overlying tuff. It forms an oval band from a mile to a mile and a half wide round the whole basin, but is separated from the acid edge by the conglomerate into which it appears to merge, more and more ordinary sedimentary material coming in toward the base until the majority of the constituents are water-formed clastics, and the transition to the Trout lake formation is complete. The edge of the pyroclastic sediments toward the nickel eruptive, like the underlying conglomerate, is generally hardened by the action of the fluids from the acid edge and so stands up as sharp hills, but the softer inward edge sinks away into the low ground and is largely covered with drift. Perhaps the best exposure for the study of the tuff is along the railway east of Onaping, though here the softer phase is mostly hidden. Good sections are afforded on the road from Trout lake to Azilda, especially on the north side of the basin, and along the southern side of the basin in Capreol and Hanmer townships.

At several points the tuff has been found to contain small deposits of sulphides, especially zincblende and galena, but never on such a scale as to be of economic importance. Such deposits are known at points to the north of Fairbank lake and along the same side of the basin toward the east, but the largest visited by us was a little east of the south end of Trout lake in Bowell township, where a location (W D 252, sometimes called Prue's mine) has been taken up, and a small shaft sunk showing quartz with zincblende, galena and a little copper pyrites. A dark gray basic eruptive rock occurs beside the shaft and its eruption probably influenced the formation of the small ore body. Pyrites is very commonly found scattered in small particles through the tuff, as near the high falls of the Onaping river, sometimes in such amounts that the surface weathers rusty; and there are places near the northeast corner of Creighton township where considerable veins of quartz with pyrites have been taken up as gold mines, but hitherto with no success.

Onwatin Slate

The black, carbonaceous slate is soft and has generally weathered so far as to be covered with Pleistocene beds; but it occasionally forms low hills, as near the east end of Vermilion lake. It has a very perfect cleavage, and the stratification, as indicated by darker bands, is cut by it at high angles. Its thickness may be fixed at 3,700 feet on the average, that being the space separating the tuff from the sandstone.

The softer phase of the Onaping tuff merges on its inner side into the black slate, which forms a third band running round the basin, usually, however, occupying the low ground and very often hidden by old lake deposits. It is best studied in the river valleys, especially along the Vermilion river from Vermilion lake east and south. Just below the exit of the river from the lake a range of low ridges of slate occurs on both sides, one of the few points where this rock rises as independent hills. At Stobie falls the river, which has hitherto run parallel to the strike, turns southward across it, causing two small falls. Apparently the slate at these points has been more or less shattered and the fissures have been filled with quartz and sulphides giving it greater resisting power than elsewhere. A small shaft has been sunk on one of these deposits of sulphides just where the river turns sharply southward, but so far as known no ore of value was found.

The most interesting feature of the black slate is the large amount of carbon contained by it, amounting to from 6.8 to 10 per cent. according to analyses made in Dr. Ellis' laboratory in the School of Science. In lot 10, con. I, of Balfour township, a little north of the bend of the Vermilion a vein of anthraxolite or anthracitic carbon was found in the slate in 1896, giving rise to the hope of finding coal in the region. An examination showed that an irregular vein ran about north and south up a hill of slate having a length as far as exposed of 70 feet and a width of 12 feet where widest. The walls are very uneven, and large horses of slate occur in the anthraxolite, which would not average more than six feet in thickness. Diamond drilling has shown

that the deposit goes to a depth of at least 100 feet, so that some thousands of tons of the anthracitic material may exist in the vein. Originally the anthraxolite entered the fissure as bitumen which gradually lost its volatile constituents and became changed to the present hard coaly material having nearly 95 per cent. of fixed carbon, an analysis of the purest specimens giving the following results:

	Per cent.
Carbon	94.92
Hydrogen	0.52
Nitrogen	1.04
Sulphur	0.31
Ash	1.52
Oxygen	1.69
	100.00

It will be seen that this contains more fixed carbon than the best anthracite;[32] and in hardness and slowness of burning also it goes somewhat beyond hard coal. In losing its volatile constituents the bitumen contracted greatly, forming small lustrous fragments, often cubical, and seldom more than half an inch in diameter; and later quartz and a little pyrites were deposited in the spaces, so that the average material contains from 25 to 45 per cent. of quartz, diminishing greatly its value as fuel.

The adjoining slate has a strike of 60° and a dip of the cleavage varying from 55° toward the south to the vertical, the cleavage being oblique to the stratification, which dips to the northwest.

North of the east end cf Vermilion lake part of the slate is very carbonaceous, soiling the hands, and here also an attempt was made to find coal. The rock dump shows a great amount of slickensided fragments having a perfect polish as of graphite, evidently resulting from brecciation and faulting. Somewhat north of the anthraxolite vein mentioned above on lot 2, con. II, of Balfour township, Mr. William McVittie has sunk a diamond drill hole for 1,000 feet without any other result than to prove that the slate goes to at least that depth.

Not far from the anthraxolite deposit zincblende with some other sulphides have been obtained from the slate or from the slaty edge of the tuffs, but the amounts are too small to justify mining. At the east end of Onwatin lake, from which the name of the slates has been derived, a pit has ben sunk upon a mass of pyrites with the idea that it was nickel-bearing, but with no results of importance. Evidently the shattering due to earth movements since the nickel eruptive reached its place has caused many fissures, some of which have been filled with molten rock, forming the diabase dikes, others with pitchy materials forming anthraxolite, probably derived from the enclosing rocks charged with hydrocarbons, and still others filled with zincblende, pyrite and other sulphides with a little quartz as a result of circulating water. Appreciable quantities of nickel or copper apparently do not occur in the sulphides deposited in the slates.

Chelmsford Sandstone

The uppermost rock of the series is distinctly marked off from the slate below, though a few bands of slate part the thick beds of sandstone and bring out prominently the bedding of the formation. The sandstone, where it rises above the plain, forms a succession of gentle anticlines, usually four in number, running parallel to the axis of the main syncline, i.e., about 50° to 80° east of north. The synclines between the anticlinal hills are always buried under stratified lacustrine deposits or under swamps,

[32] Bur. Mines, 1896, Anthraxolite or Anthracitic Carbon, by A. P. Coleman and W. Hodgson Ellis, pp. 159-166.

so that a complete fold is never seen. In almost all cases the top of the anticline has been destroyed, and often narrow, sharp, outlying ridges run parallel to the central hill, ruins of former upper beds of the anticline. In size the anticlines vary considerably, the longest mapped having a length of 2½ miles and a width of about a quarter of a mile, while the next to the northwest is only a mile long and 760 feet wide. The slopes of the folds vary from 20° or 25° to 45° or 50°, and the present height of the hills is seldom more than 150 feet above the plain formed by the old lake deposits. However, in crossing these anticlines one usually finds a more or less steep hill following the bedding and then a sharp break with a nearly vertical cliff of 5 to 15 feet, where the stratum has been destroyed. Then comes another ascent of gentler slope along the next stratum with perhaps a smaller cliff; and at last a gently rounded surface on top of the arch; the opposite side being of the same nature but reversed.

The sandstone occupies the centre of the synclinal trough, running from the west end of Vermilion lake to the east side of the township of Hanmer, a distance of 18

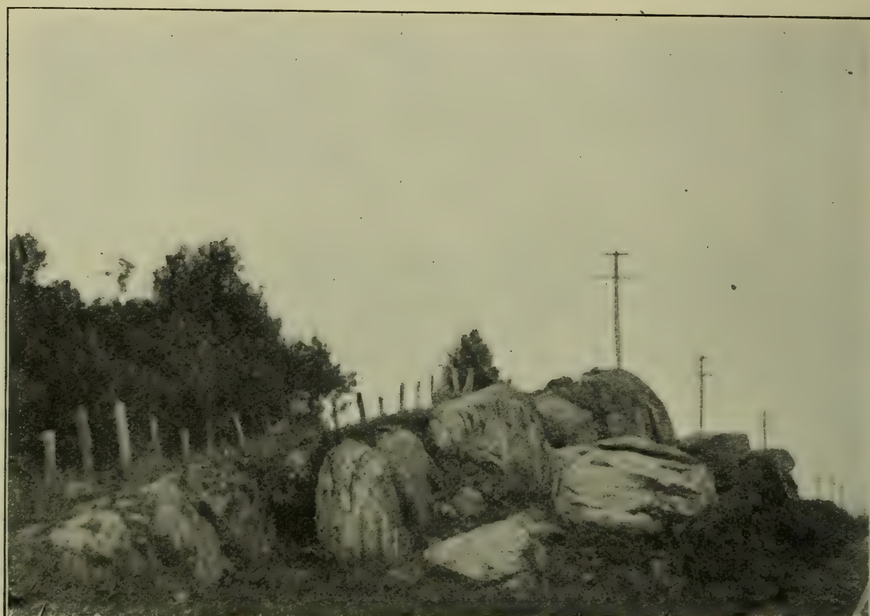
Anticline of sandstone, west of Chelmsford.

miles, with a width of about three miles. It is probable that it really extends about 8 miles farther toward the northeast, but that part of the basin is covered with old lake deposits. In general the sandstone does not form a continuous area, stretches of flat farm-land or of swamp separating the anticlines, or their ruins from one another. No attempt has been made to map the numerous small outcrops of sandstone where little ridges representing remnants of elongated domes rise a few feet above the soil with a steep face toward the centre of the ridge and a gentler slope outwards.

The road from Larchwood to the west end of Vermilion lake touches several of these outcrops and in one place runs for some distance along the nearly flat surface of an anticline; and in canoeing up the Vermilion from the lake toward Larchwood several small outcrops represent the bases of anticlines which have mostly been destroyed.

The neighborhood of Larchwood presents one of the best places to study the sandstone, sections being presented by wagon roads, the railway and the river, which here flows first parallel to the strike along a syncline to the railway bridge, where it turns southeast across the strike of a broken anticline, forming two falls, and then southwest again along the strike.

The sandstone is medium-grained with particles of quartz and of mica visible, as well as some feldspar, so that it might be called arkose. It is not very strongly cemented, is dark gray on fresh surfaces and paler gray on weathered ones, and frequently contains large oval concretions richer in lime and iron than the rest of the rock, so that they might be called impure ferruginous limestone. The large concretions weather out and leave shallow holes which give a very characteristic look to some of the flanks of the anticlines. The beds are from two to seven or eight feet thick, and often a thin seam of slate, less carbonaceous than the slate below, occupies the break



Southern edge of anticline, west of Chelmsford.

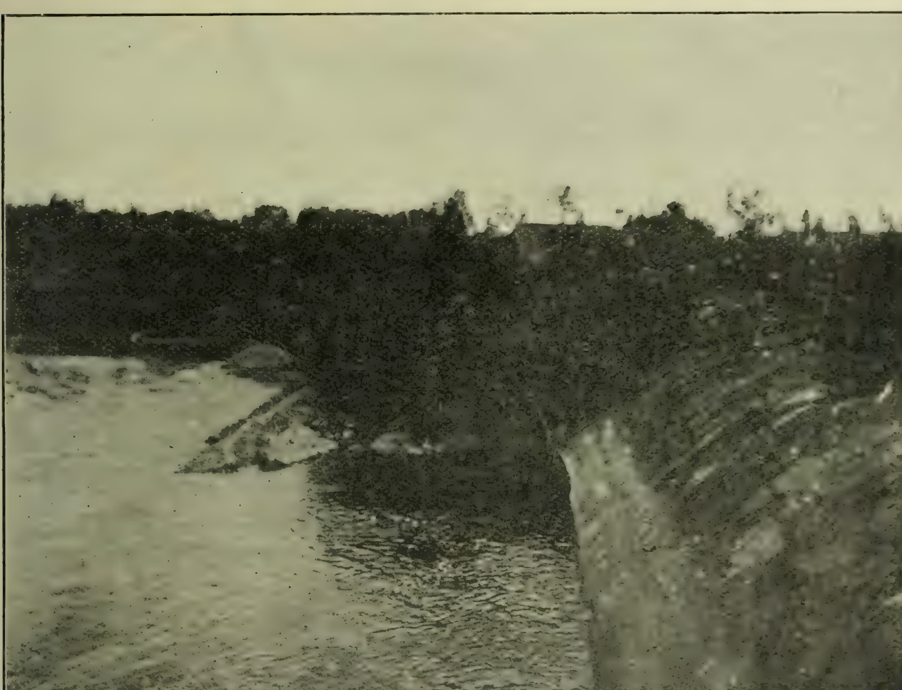
between two strata. Occasionally this slaty part of the rocks has been greatly crumpled and thickened at some points, probably while the harder sandstone underwent folding.

Between Larchwood and Chelmsford the railway runs mainly on a clay plain and seldom cuts the sandstone, the route having been chosen so as to avoid the anticlines, but both to north and south ridges a mile or two long and from 50 to 150 feet high rise above the plain with slopes ranging from 20° to 45°. The wagon road between the two places, running south of the railway, crosses several of these ridges but lies to the south of the Chelmsford ridge, one of the most extensive ones which has been rather carefully studied, and may be taken as typical.

It begins just west of Chelmsford with the appearance of a dome, small buttresses of sandstone rising a few feet above the clay with slopes of 15° to 18° toward the north, northeast, east and southeast. A little beyond Chelmsford creek and south of the railway the dome rises completely above the clay and has been quarried for building stone. The cleared surface shows shell after shell of gently rounding beds sloping toward the plain, but to the southeast a gap has been cut out of the anticline so that

a small bay penetrates the outer edge from the plain. The end of the anticline is slightly double, a very gentle depression separating a higher part to the northwest from a lower swell to the southeast. Beyond this point the anticline rises with a broken top to the height of from 75 to 125 feet or a little more, and keeps this height and a width of about 600 yards for about a mile, when it sinks somewhat irregularly with a dome-like form into the plain. The direction of the anticlinal axis is 65°, the length is 2½ miles and the width, if the outer remnants of strata which have been destroyed are counted in also, of about one-half mile. If the crest of the anticline were completed from the outer remnants with the average dip of 18° or 20° at the edges, the height would be about 350 feet above the plain.

Another anticline to the north of the railway is on a much smaller scale, but with steeper slopes, having a length of about a mile, a breadth of 700 feet, and a height



West side anticline of sandstone on Vermilion river. Larchwood.

of 80 feet, with a dip of 36° to the southeast and of 26° northwest. If it were completed its height would be about 125 feet above the plain.

An anticline at the Larchwood railway bridge has steeper slopes still, one side dipping 43° northwest into the river, the other 44° southeast under drift. It is 730 feet wide where the section was made, and if restored would have a height of about 200 feet above Vermilion river. As fully half of the folds from trough to crest is buried under the clay, we may suppose them to measure 400 or 500 feet in total height.

In order to give a complete idea of the structure of the sandstone area a section has been made across the whole width, but it was found necessary to make a jog of half a mile in one place and of a quarter of a mile in another so as to avoid large swamps. It is believed, however, that the section as worked out gives the general relationships correctly. In all, four anticlines are found, the two which have been described a little west of Chelmsford and two somewhat wider ones toward the

northwest, the last one, however, seeming much less regular than those to the southeast. Much more of the surface is covered with drift towards the southeast than toward the northwest, and the rugged sandstone ridges on the latter side are uncleared and not so easily studied as those rising out of the fields.

After the last fold on the northwest the sandstone dips gently toward the southeast with small cliffs facing in the opposite direction, and is underlain by the Onwatin slate. On the southeastern side of the folded central region there is a similar attitude of the beds, but the slate is not found, so that evidently the lower part of the series is buried. The contact of the sandstone with the slate is even better shown on the road from Larchwood westward, the slate at that point dipping 20° to the southwest under the sandstone. The dip of the sandstone near the hotel at Larchwood, about one eighth of a mile from the contact with the slate, is 42° to the southwest, and the thickness has been worked out as 350 feet.

To the northeast of Chelmsford sandstone ridges covered with woods continue some distance north of the railway to the east side of Lumsden township, where they are well exposed on the road from Azilda to Trout lake, rising first above the clay a little north of the line between Rayside and Lumsden townships, as a small ridge striking northeast and dipping 10° to the northwest. There is a cliff of 15 feet facing southeast, and this outcrop may be part of the first anticlinal ridge, the rest not rising above the clay. After three-fourths of a mile of swamp another anticline is reached toward the northwest, having a strike of 75° and a dip of 26° toward the southeast with a corresponding dip in the opposite direction.

The sandstone continues a mile or two farther to the northeast, and the anticlinal hills extend for about the same distance along the strike, beyond which plains of clay and sand cover the rock, so that the northeastern end of the sandstone area cannot be exactly determined.

SOURCES AND FORMER EXTENT OF THE SEDIMENTS

The sources of the materials of the sedimentary series are not easily explained in all cases, though the granitic pebbles and boulders of the basal Trout lake conglomerate no doubt originated in the underlying granites, especially the Laurentian; and the sand of the quartzitic layers may have been supplied by Huronian quartzite. The cherty ingredients of the upper layers may have been deposited from solution like those of the Animikie of the west.

The water-formed sedimentary materials mixed with the Onaping tuff also are easily accounted for, as they are mainly granite, quartzite and chert; but the volcanic centers from which the explosive eruptions of ash and lapilli took place remain undiscoverable. The thickness of the tuff, estimated at 3,800 feet, and the area, of about 200 square miles covered by it, if continuous beneath the slate and sandstone, indicate a total amount of perhaps 130 cubic miles of material still preserved, and this would be increased greatly if we imagine the tuff extended so as to cover the whole area of the laccolithic sheet, which was no doubt the case in the beginning. An analysis of a sample from north of Whitson lake by Prof. Walker indicates a composition not unlike the average of the basic and acid portions of the nickel eruptive, and it is conceivable that the tuff may represent an earlier eruption from the same magma, actually reaching the surface in volcanoes. Until some trace of the bases of old volcanoes is discovered this must, however, remain doubtful. Whatever the origin of the volcanic materials may have been they seem to have dropped into the sea and to have been mingled with waterworn fragments of non-volcanic rock.

The Onwatin slate may be looked on as ordinary mud mingled with organic matter, probably coming from marine plants or animals; and the Chelmsford sandstone is largely arkose, which may have resulted from the decay of adjoining Archean land.

The former extent of the sediments must have been much greater than the present, but there is very little evidence of similar rocks from the surrounding districts. The

only outside example of the tuff, so far as known, is a small patch near Bear lake, and the other rocks of the series have not been found with certainty anywhere in the region. Apparently the soft sediments have been destroyed everywhere beyond the protective wall of the acid edge of the eruptive and on the metamorphosed base adjacent to it.

Probably the most nearly similar formation elsewhere is the Animikie at Port Arthur, where black slate, chert and arkose-like rocks sometimes called quartzite occur, but the basal conglomerate there is thin, and there is nothing that suggests explosive volcanic eruptions such as formed the great sheet of vitrophyre tuff.

PLEISTOCENE OF THE SUDBURY DISTRICT

Glacial Action

The geological record of the Sudbury region, as shown in the solid rocks, ends in very ancient times, certainly not later than the Cambrian, and from that age to the Pleistocene no deposits are known, probably because the land remained above sea level. A vast amount of erosion must have taken place as shown by the cutting down of the more than 10,000 feet of sediments which once spread more widely than the present area of the nickel-bearing eruptive.

The thick sheet of residual materials which must have resulted from this prolonged period of weathering and erosion has been completely swept away or worked over by various agencies in the Pleistocene. Like all of northern Ontario, the Sudbury district shows the effects of glacial scouring in the bare and usually rounded rocky hill tops, covered with striae where the rock has not suffered from post-glacial weathering. The usual direction of the ice motion is from N. 30° to N. 45°, but in a few places more than one set of striae are to be seen; as near Copper Cliff, where later and less incised striae run N. 15°, and at Chelmsford where the usual scoring having a direction of N. 45° is crossed by later ones running from N. 60° to N. 65° It is probable that these divergent striae are due to local ice currents caused by the shape of the hills and do not indicate the work of later ice sheets coming from a different direction.

There are parts of the region where cliffs facing northeast have not suffered much rounding, as if the ice pressure had been unequal, but in general the direction of the ice movement was not far from parallel to that of the strike of the ridges, so that great abrasion can hardly be looked for. The low but sharp edged cliffs of the interior sandstone ridges, for instance, run from N. 50° to N. 80° as a rule, so that the ice advance if not parallel was only slightly diagonal to them.

Certain of the rocks, such as the basic edge of the nickel-bearing norite, crumble too quickly under the action of the weather to preserve ice markings or even *roches moutonnées* forms; but it is rather surprising to find how often the ore bodies along offsets from the norite rise as gossan-covered hills which have resisted ice erosion, as at Copper Cliff, Evans mine, Stobie mine, etc. It may be noted also that perfectly fresh surfaces of pyrrhotite, polished and grooved, were disclosed at Creighton mine when the covering of till was stripped off. It is evident that boulder clay almost hermetically seals the surfaces on which it rests.

Boulder clay and sandy varieties of till occur in many localities in the region, especially on the lee side of hills or ridges, but they cannot be traced as a continuous sheet as in southern Ontario, no doubt because this part of the area covered by the Labradorean ice was near enough to the centre of accumulation to be much more heavily loaded than farther south, so that the erosive and transporting work of the ice sheet was more effective than towards the edge where it was thinned by melting.

During the retreat of the last ice sheet morainic ridges were left in many places and erratics and perched boulders are common in various parts. No moraines have been traced in detail, the nature of our rock in this wooded and difficult country making that almost impossible; but morainic accumulations were found to be specially common near the northern nickel range.

Morainic ridges and kettle ponds occur to the southwest of Windy lake, and a long esker, beginning on the peninsula which projects into the lake on its southwest corner, runs northeast along the basic edge of the nickel-bearing eruptive for about six miles toward the valley of Onaping river.

Bouldery moraines and glacially dammed ponds are found just east of Sand Cherry creek in the north part of Morgan township, and sharp ridges of boulders run for about three miles east from the northwest corner of Lumsden township, evidently a moraine. A similar moraine is crossed by the portage between Frenchman's lake and Joe's lake in the southern part of Wisner township; and coarse morainic materials are found for considerable distances to the west of Hutton township some miles to the north of the nickel range.

Kame deposits are frequent, as at the gravel pit just west of the town of Sudbury, where irregularly stratified sand, gravel and boulders rest on a beautifully carved and scoured surface of quartzite.

Kettle Lake in drift, near McDonald's camp, Falconbridge township.

The combined action of ice and water is excellently shown in the wide plains of sand and gravel with some morainic and kame-like hills and ridges at the east end of the southern nickel range, from Headquarters toward Blue lake and Wahnapitae, where there are several kettles of various dimensions, some empty but others occupied by a pond or lake. As this region consists largely of lake deposits, however, it will be referred to more at length under that heading.

Lake Deposits

When the last ice sheet (Wisconsin?) retired from northern Ontario the drainage of the region was towards the Mississippi, and in the earlier stages the area of the great upper lakes was largely covered by lake Warren. In the later stages lake Algonquin was the representative of the upper lakes, emptying mainly by way of

Niagara, but for a time through the Trent valley, into lake Iroquois, whose outlet was through the Mohawk valley into the Hudson.

The beaches of lake Warren are probably the highest in the region, reaching 1,100 or 1,200 feet above sea level along the northern nickel range, and even 1,400 feet within 40 miles to the north, as at Meteor lake.

Cartier, somewhat to the northwest of the nickel region, is built on a gravel terrace 1,367 or 1,398 feet above the sea, representing the highest lake deposits in the district along the line of the railway, except a gravel flat near Geneva lake, 4 or 5 miles beyond, which reaches about 1,400 feet. No beaches as high as these have been found in the nickel region proper, but along the northern range somewhat lower terraces occur at many points, often three in succession. The following table gives the elevation of most of the terraces known in the Sudbury district:

	Feet.
Meteor lake—sand and gravel terrace	1,420
Geneva lake—gravel terrace	1,400
Cartier—gravel plain, (1,367 from Montreal), 1,398 (from L. Sup.)	
Lake expansion of Spanish river—gravel plains	1,335
Muskegogema lake—gravel plains	1,316
Near Onaping, Windy lake—gravel plain	1,216
" Moose creek—gravel plain	1,110
" Onaping siding—sand plain	1,057
" Phelan's siding—sand and gravel plain	927
Trout lake in Morgan township—gravel plain	1 123
Island creek—gravel plain	1,163
" lower terrace	1,057
Trout lake in Bowell township, and region to south:	
" between Trout lake and next lake	1,216
" south of 2nd lake—gravel flat	1,160
" "	1,110
North of Vermilion river—sand plain	950
Terrace along river—sand plain	926
Rayside or Azilda—clay plain	881
Hutton township, Osborne's camp—gravel terrace	1,090
Upper Vermilion river, Gordon's placer claim—gravel terrace	1,047
" " west of Bronson lake—gravel terrace	1,060
" " " " "	970
" " Dawson—main gravel terrace	958
" " One mile east of Dawson—bouldery terrace	950
North of Onwatin lake on Dawson Road—terrace	1,000
South of Onwatin lake—sandy plain	900
Near the southern nickel range:	
North of Fairbank lake—gravel terrace	1,050
North of Worthington—clay plain	775
Near Sudbury and Copper Cliff, north of smelter—sand terrace	934
Cemetery north of Sudbury—gravel terrace	877
Clay flat	850
Headquarters, east side of Garson township—sand plain	1,080

Many other terraces and flat plains of clay, sand or gravel were observed, but owing to weather conditions or length of absence from a bench-mark my aneroid readings seemed too uncertain to be relied upon. In the above table heights determined by aneroid are given in the nearest round number; other elevations, mainly determined by hand level from railway bench-marks, are given more exactly. As the hills along the northern nickel range rise, as a rule 200 or 300 feet higher than along the southern range, there were more opportunities to record the higher beaches there. Still farther

to the north near the watershed between the great lakes and the rivers flowing into Hudson bay there is a broad tract of stratified sand and gravel with numerous kettle lakes at about the level of Meteor lake (1,400 feet).

In a general way one may say that the highest terraces, say those above 1,200 feet, belong to lake Warren, and the lower ones down to about 900 to lake Algonquin. Still lower gravel terraces may belong to some intermediate stage between it and lake Nipissing. Until the connections have been worked out it must, however, remain uncertain just where a given terrace should be placed in the series of old lakes from Warren downwards. As lake Nipissing is only 648 feet above sea level, and the level of old lake Nipissing was not very much higher, it is evident that none of the water-levels of the Sudbury region belong to it, all being considerably too high.

In the highest stages of lake Warren the basin enclosed by the nickel ranges was completely submerged with only the higher hills along the northern edge standing above water as a low rocky shore or as small islands. At this time indeed most of the basin may still have been occupied by ice; but as the ice front retreated the region to the northeast was rising, so that the enlarging waters of the lake stood relatively lower and lower here towards its northern end, forming the succession of terraces mentioned.

By the time when lake Warren was drained to the lower level of Algonquin the water had so far fallen that the interior of the basin became a bay completely enclosed except at a few channels opening southwards across the southern nickel range, as along the valley of Vermilion river.

While the broad gravel plains were being constructed at the higher levels sand was being deposited in the shallow water and silt and clay in deeper parts, forming the flat plain of clay and sand standing at levels between 750 and 900 feet, affording several townships of good land now largely taken up by farmers. In general the valleys of the rivers and creeks are cut more or less deeply into these deposits showing finely stratified clay often covered with a few feet of yellow sand. Along the watercourses sand prevails for a few hundred yards or half a mile, but inland from the streams clay is found. These deep-water deposits are often quite thick and fill up all depressions in the older rocks to a common level out of which the steep walled hills rise suddenly with very little talus to blend their slopes into the plain. The contrast in coming from the excessively rugged and precipitous hills formed by the acid edge of the nickel-bearing eruptive and the hardened conglomerate and tuff to the plains of clay near Azilda or Chelmsford is very striking.

The depth of the stratified clay has seldom been determined, but in one case, north of the railway at Azilda, a well was driven to a depth of 105 feet without touching rock.

It is probable that the retreating ice occupied the region east of Headquarters for some time toward the end of the series of Warren water levels, and the stagnant ice of its edge frequently got buried under shore deposits of sand and gravel, to thaw at a later time and leave the irregular basins which are called "kettles." These have walls of sand or gravel as steep as the materials will lie with a fairly flat marshy floor drained through some pervious layer or a lake, often with no apparent outlet. One of these basins on the road to lake Wahnapitae is three-quarters of a mile in length by a quarter of a mile in breadth, and 165 feet deep. Part of the bottom is occupied by a pond said to be 60 feet deep.

The source of the materials for the large gravel plains along the northern nickel range and farther north toward the height of land is to be found probably in glacial gravels of a kame-like character which the waves of the great lake at the front of the ice distributed as they were brought down by the sub-glacial rivers, which have left behind esker ridges in various places.

Distribution of Lake Deposits

The lacustrine clay which includes most of the farm land of the Sudbury region has almost the flatness if not the extent of the prairies, and covers not alone large tracts in the interior basin but also to the south of the nickel range. In the interior basin clay land suitable for farming begins along the shores of Vermilion lake in the north half of Fairbank township, fine groves of maples and other deciduous trees occupying a mile or two along the northwest side of the lake on low land of a silty nature. To the east the flat clay plain with some ridges of slate rising through it extends to the southward bend of the Vermilion river and as a narrow band along the river valley to the falls (17 feet) in the southeast corner of Creighton township, and

Farm land, Azilda ; from cliff of Acid Eruptive.

then to the north shore of Whitewater lake, where it projects some distance into the acid edge of the nickel-bearing eruptive beyond Rayside or Azilda. The two southward extensions of the clay occupy parts of two low passes in the southern rim of the basin, the exit of Vermilion river, which carries the whole drainage of the basin, being of course the lower of the two, having a level of about 800 feet above sea level.

The southern clay band then turns northeast through parts of the townships of Rayside, Blezard, Hanmer and Capreol, in the latter township becoming silty and sandy, but still affording good land now being rapidly taken up by settlers. At the southeast end of Capreol the loamy plains give place to glacio-lacustrine plains of gravel with kames and moraines and kettle holes, as mentioned earlier, unfit for farming; and to the northeast rise the hills of the acid edge.

To the northwest of the clay belt just referred to good land extends into the southern half of Dowling, here becoming more sandy in character until it merges into the sand and gravel plains along the northwestern margin of the basin. Except for anticlinal ridges of the central sandstone there is good clay soil from Larchwood to Chelmsford and on northeastwards to Hanmer township. Along the Vermilion river

and to the north of it the lowland consists mainly of useless sand and gravel plains with stony gravel terraces in the openings of the hills along the acid edge of the northern nickel range. The villages of Chelmsford, Larchwood, Azilda and Blezard Valley are growing up as prosperous centres for the farming region.

South of the nickel range the areas of good clay land are more scattered and of less extent, owing to the more resistant character of the Archean rocks as compared with the sediments of the interior basin. A considerable number of farms extend from Sudbury north to Stobie and northeast intc Garson and Neelon townships; but farther northeast the land becomes sandy and passes sinto gravel plains near Headquarters.

There are small areas of good soil southwest of Sudbury along the Sault branch of the Canadian Pacific near Copper Cliff, Naughton, Whitefish, Worthington and other points, each occupied by a few farmers; and there are still wooded tracts of rolling clay land to the north of the railway in various places suitable for settlement.

More or less good land extends along the lcwer ground adjoining the Sault line to Lake Huron, Sault Ste. Marie and Goulais bay on Lake Superior; but this goes beyond the district now under consideration. In these western regions as toward the east, one finds the low-lying clay rising toward the north and becoming mixed with sand, ending with sand and gravel terraces along the rocky hills which rise a few miles from the shore of the lake.

Gravel Plains and Terraces

Gravel plains, or flats of sand and gravel, extend between the Archean hills far to the northwest of the Sudbury district, and have been put to use by the Canadian Pacific railway, which always locates its sidings and stations on such plains if possible. Within the limits of our map such plains exist near Geneva lake, at Cartier, at Windy lake siding and at Phelan's, the last point being within the basin here described. The gravel plains around Phelan's and Onaping extend northwards along the Onaping valley to the mouth of Moose creek. Similar sand and gravel terraces stretch bay-like into all the river valleys which come south through the northern nickel range, as along Island and Sand Cherry creeks in Morgan township, Nelscn river and the region south of Trout lake. They are found too along Rapid river and south of the Frenchman's lakes in northern Hanmer extending to Vermilion river north of Onwatin lake.

Away to the north for 40 miles sand and gravel with eskers, kames and kettle ponds and lakes extend along the Vermilion, the head waters of the Wahnapitae and around Meteor lake, itself an immense kettle walled with gravel.

This irregular chain of gravel plains running up from 1,050 feet above sea in the south to 1,400 in the north at the watershed is of interest as containing placer gold, sometimes 50 or 100 very fine colors being got in a pan, though usually the number is much less.[33]

Southeast of the east end of the nickel basin is the large sand and gravel area referred to before near Headquarters, including parts of the townships of Capreol, Maclennan, Garson and Falconbridge, and covering for a space the basic edge of the southern nickel range. Here, as on the Vermilion south of the west end of the range and also along the line of the Canadian Pacific west of Sudbury, there is a sinking in the hardened tuffs and the acid edge of the nickel-bearing rock, which in the later times of the glacial lakes formed a channel between the bay enclosed in the basin and the broad lake to the south and west.

The sandy and gravelly terraces and plains were formerly covered with a good growth of pine, but in most parts this has been cut, and too often fire has run since, reducing the plains to barren wastes or a low scrub of second growth jack-pine.

33 Bur. Mines, 1897, pp. 256-9; and 1901, pp. 151-9.

PETROGRAPHICAL SECTION

Petrography of the Nickel Eruptive

Since it was discovered by Professor T. L. Walker in 1897 that the basic rocks associated with the Sudbury nickel ores pass by insensible gradations into acid rocks having the composition of granite, it has been difficult to give a petrographical name to the whole mass of eruptive rock, now known to form a synclinal sheet a mile and a quarter thick on the average. It would be manifestly incorrect to name it either norite or granite, so that hitherto in this report non-committal terms such as the "nickel eruptive" or the "nickel-bearing eruptive" have been employed. Before Prof. Walker's discovery the basic side of the sheet was mapped separately as greenstone, and such names as diorite and diabase were applied to it, naturally enough, since the ordinary weathered phase shows no pyroxene, and to a certain extent there is a suggestion of ophitic structure in the rock. In 1892 Baron von Foullon showed that the fresh rock at Murray mine is norite; and it is certain that one of the samples from a supposed dike at the Blezard mine, sent by Dr. Bell to Prof. G. H. Williams for identification, and named quartz-hypersthene gabbro, was really from the basic edge of the eruptive, so that the true nature of the rock had already been shown in 1890.[34] In 1893 the present writer noted the presence of gabbro containing diallage and enstatite associated with ore in the northern nickel range.[35]

The acid phase of the sheet has been variously named syenite, gneiss, granite and micropegmatite, and there is some justification for all of these names, since the rock contains considerable quartz, but almost always pegmatically intergrown with feldspar, so as to be invisible to the naked eye, and there is frequently a distinct gneissoid or schistose structure. In former reports on the region the acid side of the eruptive has been mapped in many cases as Laurentian gneiss but occasionally as a Huronian schist, and never as granite or syenite, except by Prof. Walker in the sketch map accompanying the paper mentioned before. That the rock was a micropegmatite in structure was noted by the present writer in connection with the northern range, but it was not observed that the basic and acid phases belonged to the same sheet of eruptive rock.

Excellent accounts of the nickel eruptive have been given by Prof. Walker in his Inaugural Dissertation and by Dr. Barlow in various Geological Survey reports, especially his latest, published in 1904;[35] and detailed accounts of the rock as shown in various sections across the eruptive have been given in former reports of the Bureau of Mines.[36] Since the last report was written the eruptive has been examined, in some new localities, and it will be useful to give the results as a whole in this final report on the region.

That good sections across the whole width of the eruptive are found along the C. P. R. between Murray mine and Azilda, and near Onaping, has been well shown by Prof. Walker; and several other fairly good sections occur at some of the lakes, such as Fairbank lake, Whitson lake, Blue lake and Joe's lake. Some of the wagon roads of the region also give good exposures, as from Blezard to the north end of Whitson lake, and between the Emery Headquarters and Capreol township. Most of these sections, which are from three to four miles long, have been briefly mentioned in the detailed account of the nickel ranges. One very interesting section across the narrowest portion of the range in the northeast part of Morgan township is very inaccessible, but specimens have been obtained from each edge.

Two of these sections may be chosen as typical, the ore from Murray mine to Azilda and the section at Onaping.

34 G. S. Can., 1890, Part F, p. 77.
35 Can. Rec. of Science, Apr., 1893, p. 344.
35 G. S. C., Vol. XIV, Part H.
36 Bur. Mines, 1903, pp. 293-6; and 1904, pp. 208-213.

THE MURRAY MINE SECTION

The norite near the Murray and Elsie mines is dark gray, coarse-grained, and contains blebs of blue quartz and flakes of mica, which are easily seen without a lens. There is a tendency to the ophitic structure in some specimens but not in others, and there is a great difference as to freshness. The rock weathers readily into rounded forms half embedded in coarse sand resulting from its own decay.

Fresh thin sections consist mainly of plagioclase and hypersthene with a little augite, quartz and biotite, the plagioclase having the extinction angles of labradorite. The feldspar makes up two-thirds of the rock in my best section and the hypersthene a quarter, the latter mineral being pleochroic. There are also a slightly pleochroic augite in small quantities, a little biotite, and a very little hornblende. Sometimes the hypersthene has good crystal forms against the feldspar and sometimes the reverse. Quartz forms wedges between the rather platy feldspars, which are fresh but have a pale brownish color.

Canadian Copper Company's new smelter from northeast.

A specimen from the mine itself, containing several per cent. of ore differs from the one described in having less plagioclase than hypersthene and very little quartz, and there are also variations in the amount of biotite, so that the proportions of the minerals normally forming the rock are somewhat uncertain.

Most of the norite from Murray and Elsie mines is however no longer fresh enough to retain the pyroxene, which has been transformed into rather compact-looking hornblende in some cases, and in others to uralite or serpentine. The plagioclase remains fresh, however, and the biotite seems unchanged.

For a mile and a half to the northwest along the railway there is little change in the norite, except for an increase in the amount of quartz which has more or less of a graphic intergrowth with the feldspar, but beyond this the weathered surface of

the rock becomes reddish and suggests a dark syenite. Thin sections disclose quartz and plagioclase with biotite, secondary hornblende and apatite, the first two minerals largely intergrown as micropegmatite which radiates from a crystal of andesine. There may be a little orthoclase, but in the main the feldspars are of the soda-lime varieties, so that the rock should be named micropegmatitic quartz diorite.

Nearer the acid edge of the eruptive the rock does not change much in appearance except to grow more schistose, and thin sections differ only in containing more micropegmatite and also more unstriated feldspar, so that it should be classed as pegmatitic granodiorite or granite. Where the schistosity is pronounced there is often too much crushing to show the micropegmatite distinctly.

The series collected on the road from Blezard north to the end of Whitson lake is very similar to that just described, except that there is less schistose structure toward the acid edge. The norite at a point a little north of the mine was found by Prof. Walker to be the freshest in the region, and thin sections are very handsome. Plagioclase (labradorite), hypersthene, diallage and biotite make up the most of the section, but some hornblende, probably secondary, quartz partly as pegmatite, and apatite are found also.

Prof. Walker has published analyses of specimens taken somewhat to the east of the road along the shore of Whitson lake and his results will be given later along with rock analyses from other parts of the range. His work shows an increase in silica, potash and soda from south to north and a decrease in lime and magnesia, corresponding to the change in mineral composition of the rock.[37] Both of the sections just described include considerable masses of granite and of re-arranged arkose, which have been left out of account in the description.

THE ONAPING SECTION

The best section across the northern nickel range is one which Prof. Walker first described, following the railway from Windy lake to Onaping from basic to acid edge, reversing the order found at Murray and Blezard mines. Railway cuttings provide a very complete series of specimens which differ considerably in appearance from those described from the southern range.

At the basic edge the rock is rather coarse-grained and of a much lighter gray color than the corresponding rock at Murray mine. There follow syenitic-looking rocks made up of flesh-colored and green minerals, and finally near the acid edge greenish gray rocks rather finer-grained and with lath-shaped feldspars. No part of the series is schistose, indicating less squeezing and shearing than on the southern range.

Going eastwards along the railway from Windy lake siding Laurentian is seen for a quarter of a mile, when drift and an esker ridge cover the rock for a distance. At the northwest end of Windy lake gray, dioritic-looking norite crops out, rather coarse and speckled in appearance, consisting, as seen under the microscope, mainly of plagioclase, hypersthene and augite, with a little quartz, biotite, and hornblende, many prisms of apatite and some magnetite. The plagioclase, which is clear and colorless and makes up about half of the rock, has extinction angles corresponding to andesine or labradorite, and is generally hypidiomorphic; while the hypersthene is idiomorphic. This mineral presents some anomalies, since some crystals showing the usual pleochroism, red brown, pale brownish green and pale yellowish, have parallel extinction, while others extinguish at various angles up to 28 degrees. Diallage, brown and fibrous-looking, non-pleochroic,and with an extinction angle of about 45 degrees occurs in small quantities also; the small amount of hornblende present forms margins about the minerals just mentioned; and the brown biotite is present only in trifling quantities.

A specimen from a cutting a hundred yards east is coarser grained and not quite so fresh, but daes not differ greatly in composition. An analysis of this rock given

[37] Quar. Jour. Geol. Soc., Vol. LIII, p. 56.

later, shows 56.89 per cent. of silica, considerably more than Professor Walker found in norite from Blezard mine on the southern range.

Fifty yards farther east coarse red syenitic-looking rock begins and lasts to Onaping station, showing in various cuttings. Thin sections prove, however, that the rock contains a large amount of quartz mostly pegmatitically intergrown with feldspar, but partly as fairly large clear spaces, so that it is too acid for syenite, and an analysis given later confirms this by showing 68.48 per cent. of silica. The feldspars are very badly weathered, but the well formed crystals making the starting point for micro-pegmatite seem to be all plagioclase, though the analysis proves that potash and soda are present in about equal amounts, (K_2O 3.36, Na_2O 3.72), so that the feldspar in the pegmatite must be chiefly orthoclase. The dark minerals include secondary looking hornblende and the mineral resembling epidote named by Professor Walker woehlerite. The last specimen collected to the west of Onaping station has extraordinarily slender prisms of feldspar, which strike the eye immediately on frosh surfaces.

To the east of the station the appearance of the rock changes and it becomes greenish gray and finer-grained; though the microscope shows little difference except the presence of more hornblende. An analysis proves that this rock is less acid than the red variety west of Onaping, since it contains only 61.93 per cent. of silica.

At the margin of the eruptive against the basal conglomerate beneath the tuffs, it becomes finer-grained, though still green and dioritic-looking; and thin sections show short, stout crystals and little micropegmatite, the quartz, which is present in considerable amount, being mostly granular.

The sections just described may be looked on as typical, since they include fresh norite and cover the full width of the eruptive, four miles on the southern range, and about two and a half in a straight line on the northern. Each begins with quartz-biotite-norite on the basic edge, passes through intermediate stages in which micropegmatite occurs in increasing amount, and ends in a rock consisting mainly of micropegmatite enclosing crystals of andesine with hornblende and biotite, having a chemical composition corresponding to grano-diorite. There is one very important difference between the southern and the northern sections, which are arranged in opposite directions to one another, each having its basic edge outwards from the central line of the eruptive sheet. The southern range has a mile and a half or possibly two two miles of the more basic rock, norite; while the northern range has only a quarter of a mile which can properly be reckoned to ncrite. The acid portion of the sections is about equal, but the basic portions are very unequal. This probably has some bearing on the fact that large amounts of nickel ore occur on the part of the southern range selected for study, while no ore is found at the basic edge of the northern range where the section was made and where the norite is small in amount.

It is of interest to compare with the sections just given the rocks found at the basic and acid edges of the narrowest part of the northern range, near the northeast corner of Morgan township. The specimens show little difference to the eye, though the one from the acid edge has a faint tinge of flesh-color which is lacking in the other. Thin sections show considerable differences, however. One from the basic edge contains mainly feldspar with micropegmatite radiating from it, hornblende and chlorite, the feldspar being largely plagioclase not far from andesine in optical characters, but with some untwinned crystals, probably of orthoclase, and one peculiar crystal, unstriated but containing irregular patches of plagioclase having low extinction angles from twin planes. Micropegmatite running into areas of unmixed quartz makes about a fourth of the section. The augite, partly very fresh, is nearly colorless and not appreciably pleochroic. The rock has not the usual character of the basic edge, being without hypersthene (or pleochroic pyroxene) or biotite among dark minerals, and containing a good deal more than the usual proportion of micropegmatite and orthoclase. One may hold that the true basic edge is absent at this narrow portion of the eruptive, and that the rock just described belongs to the intermediate facies between the basic and acid edges.

A thin section from the opposite or southeast side of the band consists mainly of very fine, often plumy, micropegmatite, sometimes arranged round broad crystals of andesine, sometimes about a narrow strip or about no apparent nucleus.. This makes up at least two-thirds of the rock, while plagioclase and a crystal or two of orthoclase with hornblende and a small amount of epidote make up the rest.

At this very narrow point the typical acid edge phase of the eruptive is well represented, and the lack of width is due to the absence of the basic or noritic phase. Along with this goes the total lack of ore or rusty surfaces so far as known along this part of the outer edge of the laccolithic sheet.

While the typical rocks of the nickel eruptive are dark gray or pale gray norite at the basic edge, somewhat flesh-colored pegmatitic rocks at intermediate points, and flesh-colored or greenish gray micropegmatite rock having the composition of granodiorite at the acid edge, there are, nevertheless, considerable variations in the appearance and composition of the basic edge at different parts on the circumference of the sheet, and some interesting varieties in the acid edge also; and a few characteristic localities will be taken up in illustration, especially from the southern range, where the greatest variations are found.

In the first place, it may be shown that the norite in connection with ore bodies is not always quite the same in character as that of the Murray mine, and for this purpose examples from other parts of the southern range will be studied.

Other Norites of the Southern Range

Except that the hypersthene and diallage are usually completely weathered to fibrous hornblende or uralite the basic edge southwest of Murray mine as far as Lady Violet mine differs little from the typical example, and the same is true toward Blezard mine. An interesting diamond drill hole sunk by Mr. J. V. Miller for the Edison party in lot 8, con. II, of Blezard township, more than a mile northwest of Little Stobie mine should be referred to. The drill reached a depth of 1,030 feet, and an examination of portions of the core at every 50 feet, provided by the kindness of Mr. Miller, shows that the rock is norite to the full depth except for micaceous schist with pyrite and vein quartz at 264 feet and fine-grained flesh-colored granite at 900 to 950 feet, probably from a dike. Thin sections show that the rock varies greatly in freshness, being generally so far re-arranged as tc contain only hornblende, etc., in place of the pyroxenes; but curiously the lowest parts of the core are much less fresh than the rest, though the best preserved section is from 550 feet. In it the feldspars (andesine to labradorite) are very fresh and somewhat brownish and there is a little quartz, partly interstitial and partly intergrown with feldspar as micropegmatite; while the dark minerals include much hypersthene and also a pleochroic monoclinic pyroxene very like the hypersthene, a little diallage, hornblende and biotite.

It is evident of course that the term weathering as employed for deep seated changes in eruptive rocks, like the norite at 1,000 feet, is not to be taken in a literal sense, as due to water with carbon dioxide or oxygen. Probably the different states of the rock as to freshness are due to differences in the amount of shearing or crushing allowing water to circulate more freely in some parts than others.

THE CREIGHTON NORITES

The norite of the Creighton mine differs considerably from that at Murray mine, containing usually appreciable amounts of quartz, often micropegmatitic, and orthoclase or microcline, in addition to the usual plagioclase and dark minerals. The hypersthene is fairly fresh in most sections, even those containing ore, and has a strong pleochroism. Biotite is plentiful, and the hornblende usually present seems to be secondary. The most interesting sections are those containing considerable amounts of pyrrhotite and chalcopyrite, which may lie in contact with any of the rock-forming

minerals, but are mostly found in or beside the darker ones, especially the biotite. The ore is often completely enclosed in biotite and may be accompanied by magnetite, distinguished by its iron black color and bluish lustre, the two minerals appearing to have been formed at the same stage of cooling. The sulphides, however, often show a tendency to penetrate the fissures of adjoining minerals, being evidently more easily dissolved and re-deposited than the magnetite.

It is rather surprising to find minerals like orthoclase, microcline and micropegmatite in connection with the ores at the largest nickel mine, and the fact suggests that the more acid phases of the ncrite are sometimes associated with ore bodies.

Sections of ore often show small quantities of rock-forming minerals enclosed in pyrrhotite, plagioclase, quartz and secondary hornblende being found in that position.

To determine the composition of the rock (free from ore) at the Creighton open pit Mr. M .T. Culbert has made an analysis of a fresh specimen, with the following results:

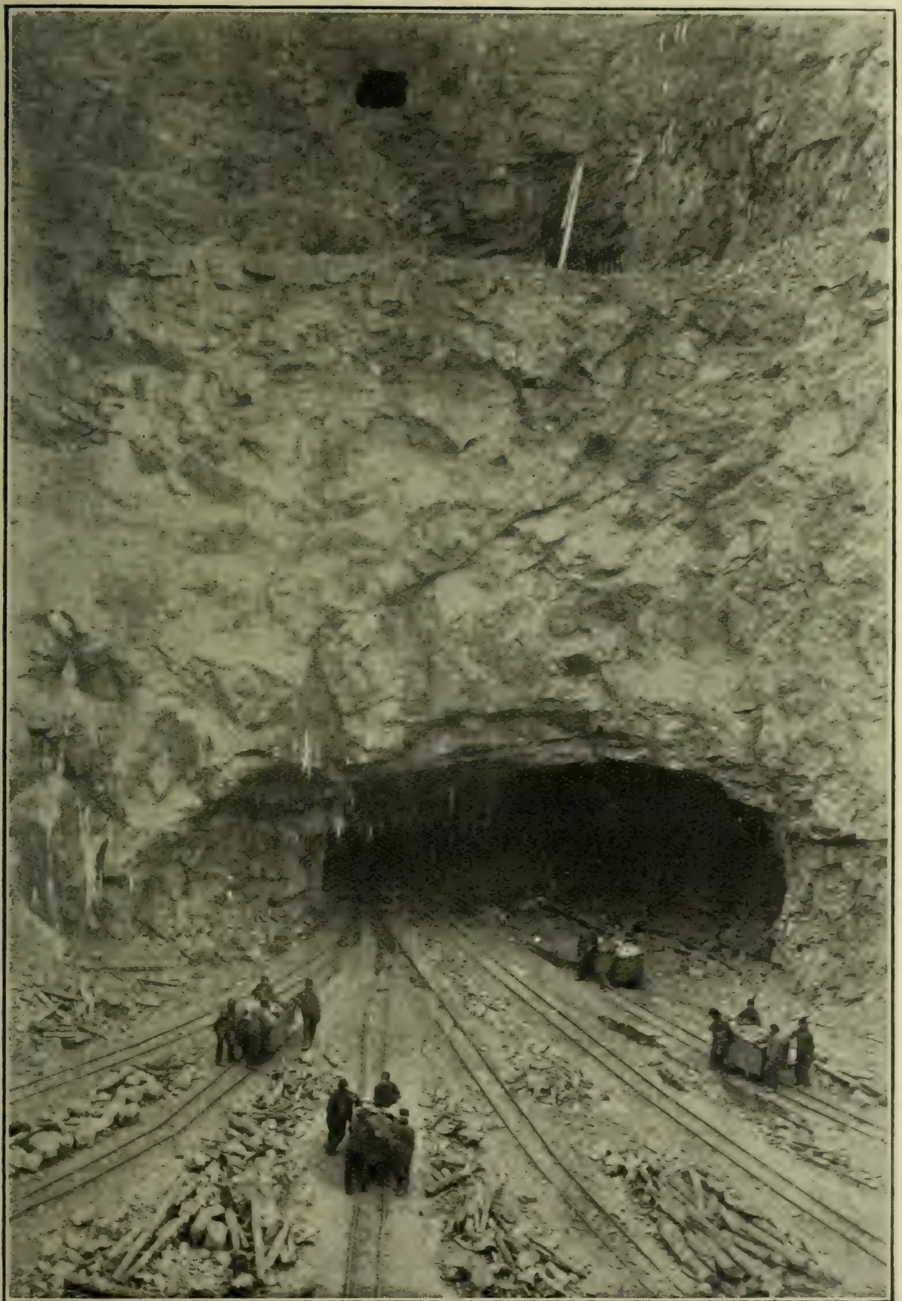
	Per cent.
SiO_2	60.15
Al_2O_3	18.23
Fe_2O_3	1.51
FeO	6.04
MgO	3.22
CaO	4.01
Na_2O	1.28
K_2O	1.68
H_2O (below 100°)	.19
H_2O (above 100°)	.36
TiO_2	1.34
P_2O_5	.23
MnO	.29
BaO	.25
ZrO	.14
NiO	.17
Cu	.16
S	.54
Total	99.79

From the analysis it will be seen that the rock cannot be called basic, the orthoclase or microcline and quartz present having raised the silica to over 60 per cent. A small amount of sulphides and of titaniferous iron ore are shown to exist, which is to be expected under the circumstances. If this rock were not in continuity with the norites east and west there would be doubt as to its position in the classification.

The rock associated with the Gertrude mine to the west is generally more weathered than at the Creighton, and seldom retains the hypersthene. On the whole it contains less quartz and little or no potash feldspar, so that it more nearly resembles the Murray mine norite. One specimen from near the Gertrude station contains a large amount of olivine in addition to hypersthene and diallage among dark minerals, but it is not certain that it belongs to the nickel eruptive; since a hill of "older norite" is a little to the south, and the immediate surroundings are drift covered.

The rock near North Star to the northeast of Creighton is the normal weathered quartz norite, and the same is true of examples from near the Victoria mine, the Chicago and the Sultana toward the western end of the southern nickel range.

Northeast of the Blezard mine the norite, where studied, is seldom dark gray in color and is frequently squeezed and sheared into schistose varieties, as at the Kirkwood and Cryderman mines. At the east end of the nickel range near Blue lake and the Whistle mines the band of eruptive is narrow and the noritic portion has suffered most, being only a few hundred yards wide. The norite is usually rather pale gray, though some areas of dark gray rock occur not far from the Blue lake mine. All the thin sections examined are greatly weathered, the pyroxenes having completely changed to uralite and even the feldspars showing to some extent the change to epidote, zoisite, etc., usually called saussuritization. The sections contain more than the normal amount of quartz, often in the form of micropegmatite, and if they had not been taken from near outcrops of ore they would probably be placed in an intermediate place between the norite and the micropegmatitic granites.



Creighton mine, second level.

The norites from the northern nickel range conform pretty well to those described from the vicinity of Onaping, having usually a paler gray color than the norites of the southern range, due to the absence of brown coloring matter in the feldspar. In general there is more quartz and micropegmatitic on the northern than on the southern range, probably because the basic edge of the eruptive is narrower there.

A few words should be said of the acid segregations occurring at various places in the norite, especially near Murray and Elsie mines. These may be small patches a square foot in diameter or several feet in diameter, the outer edge dark green from an accumulation of hornblende, then a coarse mixture of hornblende and white plagioclase followed by plagioclase alone or with some quartz.

Sections from the green edge show the same minerals as the weathered norite, but the hornblende is in much larger amount than is usual in norite, and there is much quartz and less plagioclase; but no pegmatitic structure. The next band, with a mixture of green and white, differs mainly in having less hornblende and some orthoclase or microcline with the plagioclase; while the whiter parts contain very little hornblende and consist of feldspar and quartz. Varieties of the rock in these segregations are made up of very large crystals, the blades of hornblende sometimes reaching six inches in length.

NORITE OF THE OFFSETS

Norite projects as three long offsets from the basic edge of the laccolithic sheet, at Copper Cliff, Victoria mine, and from the middle of Bowell township to the middle of Foy. There is also an isolated band of norite running parallel to the basic edge, including the Frood and Stobie mines. These projections are somewhat dike-like, but are usually very irregular in width and may run out into small separate patches of norite completely enclosed in the country rock. In a general way the norite of the offsets has the same composition as that of the main range, but it is less fresh, very seldom retaining the pyroxenes, and usually is much finer grained. The Copper Cliff offset has been most carefully studied and will be taken as typical.

In general the norite is rather dark gray and fine-grained, frequently spotted with ore, but there are also very coarse-grained segregations on a small scale, like those at Murray mine, the central parts consisting of plagioclase crystals more than a square inch in cleavage surfaces. Thin sections show plagioclase (andesine or more often labradorite) in greatest amount, followed by secondary hornblende, quartz and biotite, with more or less titaniferous magnetite sometimes surrounded with leucoxene and apatite. The quartz is partly wedged in between the feldspars, but often intergrown with them in a way somewhat different from ordinary micropegmatite, having a slightly granular look, but with many grains oriented alike. Possibly this represents a poikilitic arrangement rather than micropegmatite.

At No. 2 mine, north of Copper Cliff the pyrrhotite-norite forms only a narrow band between the ore body and the walls of granitoid gneiss. A section from a specimen five feet from the gneiss is fine-grained and has the characters just described, but with an unusually large amount of micropegmatite and a tendency to zonal structure in the plagioclase crystals, which grow more acid at the edges.

Another specimen from the actual edge of the gneiss is compact in appearance, showing more rapid cooling than the former one, and is formed mainly of tiny strips of plagioclase with parallel strips of quartz having a rough fluidal structure. The dark minerals are hornblende and biotite.

Sections from the Mitchener mine near Worthington on the Victoria mine offset have the same character as those from the Copper Cliff, but portions of the band of norite have been much more completely changed at the Worthington mine itself, being reduced to a fibrous mass of actinolite with only traces of other minerals.

From the Foy apophysis only two sections have been studied, one at its starting point and the other at the western end six miles away. The specimen from the starting point on location W D 152 in Bowell township comes from a peculiar crush conglomerate of coarser norite, and sometimes other rocks, cemented by fine-grained norite

with sulphides. The matrix is very fine-grained quartz norite, without micropegmatite, the dark minerals being hornblende and biotite. The plagioclase crystals are often well formed and have a gradual change of composition from the centre outwards.

The rock from the end of this offset is fine-grained and spotted with small specks of ore. It differs from the other mainly in having an unusual amount of micropegmatite radiating from well formed plagioclase crystals.

Variations of the Acid Edge

The acid edge of the nickel eruptive shows less variety than the basic edge, but has certain differences from the typical examples already described, which were micropegmatites of about the composition of grano-diorite. In the northern range the rocks from near Blue lake deserve mention for their marvellously developed micropegmatite, ranging from almost invisible structures to comparatively coarse ones, centring about very complexly twinned plagioclase. Specimens from Trout lake are equally fine; but sections from Moose lake have only rude intergrowths of quartz and feldspar. Almost all sections from the northern range contain considerable amounts of epidote in large, compact individuals.

Along the southern range the acid edge on Fairbank lake and points to the west and north proved puzzling in the field, since it presented exactly the dark green, fine-grained appearance of a slightly schistose greenstone. However thin sections prove that this rock also is an acid phase of the nickel eruptive, since it consists largely of the finest possible micropegmatite, invisible except with fairly high powers of the microscope, with plagioclase crystals, chlorite and hornblende. It was thought that these dark green phases of the acid edge might have acquired their color by "overhand stoping" and absorption of the lower part of the overlying tuffs, since on Fairbank lake at least the basal conglomerate in places seems almost absent. An analysis of a characteristic specimen shows, however, that the composition is normal, having 68.95 of silica, 12.74 of alumina, 3.28 of potash and 3.80 of soda. Evidently the green color simply means that the fine scales of chlorite are distributed in such a way as to give the greatest effect.

A grey green, schistose variety is found northeast of the Cryderman mine at the northwest corner of Falconbridge township also; but in this the crushing seems to have gone so far as to destroy the micropegmatite altogether.

The acid edge in some places immediately beneath the Trout lake conglomerate shows small cavities with green epidote enclosed in a rim of flesh red, the whole an inch or two across and surrounded by the ordinary grayish flesh-colored rock; and similar green and red patches sometimes occur in the matrix of the conglomerate.

General Character of the Nickel Eruptive

Having taken up typical sections of the nickel eruptive and variations from the types along the basic and acid edges of the sheet, we may now sum up our knowledge and discuss the results of rock analyses from different parts of the region.

In a general way, the basic edge may be defined as quartz-norite of a somewhat acid type for a member of the gabbro series. Plagioclase running from labradorite to andesine, but generally the former, makes up more than half the rock, sometimes almost two-thirds. Along the southern range the plagioclase is usually pale brown in color and slightly opaque, on the northern range clear and transparent; and the crystals are often well shaped with a tendency to platy forms. Quartz occurs as bluish grains and also as a wedge-shaped filling between the plagioclases; also to a varying degree as micropegmatite. In the latter case there may be appreciable amounts of orthoclase or microline. The dark minerals, when fresh, are mainly pyroxenes, the rhombic species, hypersthene or enstatite, being in largest amount, making perhaps a sixth of the rock; but monoclinic augite in the form of diallage is almost always present, and often a pleochroic augite precisely like the hypersthene, but with a distinct extinction angle, occurs also. The hypersthene is often in fairly well formed elongated

crystals. There is often some hornblende even in very fresh sections, and this in some cases at least is primary. It may form solid rims about the pyroxenes. Brown biotite in quite large individuals is almost always found, though it makes only a small proportion of the rock. Titaniferous magnetite and apatite are always present, and often pyrrhotite or chalcopyrite where the specimen is taken from near an ore body, and the freshest specimens are usually found in that position. Dr. Barlow has found a small amount of olivine in one thin section from Little Stobie,[38] but this mineral has been found nowhere else except in a doubtful specimen from Gertrude.

The weathered norite, formerly called diorite, is much more common than the fresh, but in general appearance the two scarcely differ, though the fresh rock more often crumbles with boulder-like forms under exposure than the so-called weathered rock. The change from the fresh norite is due mainly tc the re-arrangement of the pyroxenes to form fibrous hornblende or uralite or less often chlorite or serpentine, with some separation of iron oxides. The labradorite is apt to be fresh long after the hypersthene has disappeared. Weathering is less pronounced close to ore bodies than at a distance from them.

The norite blends gradually into micropegmatitic quartz diorite or syenite, coarse-grained and flesh-red on weathered surfaces, gray on fresh ones. The main difference is the increase in the amount of quartz intergrown with feldspar and the partial or complete absence of hypersthene or augite. Large grains of epidote are generally present.

This intermediate rock passes on the acid edge into quartz-diorite, granodiorite or granite containing large amounts of micropegmatite, sometimes three-fourths of the whole. The nucleus of the granophyre structure is almost always a plagioclase not far from andesine, and there is generally some orthoclase in addition to that included in the micropegmatite. The plagioclases are often plate-like. As dark minerals there are always hornblende, mica and magnetite, usually also epidote. The macroscopic appearance of the rock is often that of a medium or fine-grained syenite or granite, but it may take the form of gneiss or felsite schist or of fine-grained green schist, though the composition does not greatly vary.

In order to show the changes from the basic to the acid side of the eruptive Prof. Walker has published several analyses of samples from the Blezard-Whitson lake cross section;[39] and to complete our knowledge of the subject several more analyses are added here. The finding of micropegmatite and microcline in fresh norite at the Creighton mine made it desirable to have an analysis of the rock (No. 2), and it was also thought well to know the composition of the green schistcse rock of the acid edge at Fairbank lake (No. 8). The analyses are given in the following table:

—	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
SiO	56.89	60.15	49.90	51.52	68.48	64.85	61.93	68.95	69.27	67.76
Al_2O_3	19.39	18.23	16.32	19.77	12.70	11.44	13.03	12.74	12.56	14.00
Fe_2O_3	.38	1.51	....	.47	2.41	2.94	.56	.46	2.89	....
FeO	7.11	6.04	13.54	6.77	4.50	6.02	8.00	5.15	4.51	5.18
MgO	2.11	3.22	6.22	6.49	.74	1.60	1.76	1.57	.91	1.00
CaO	8.11	4.01	6.58	8.16	1.41	3.49	4.02	1.72	1.44	4.28
Na_2O	3.31	1.28	1.82	2.66	3.72	3.92	3.18	3.80	3.12	5.22
K_2O	1.04	1.68	2.25	.70	3.36	3.02	2.80	3.28	3.05	1.19
H_2O	1.35	.55	.76	1.68	1.13	.78	1.95	1.50	.76	1.01
TiO_2	.43	1.34	1.47	1.39	.61	....	.84	.43	.78	.46
P_2O_5	.11	.23	.17	.10	.20	.24	.32	.20	.06	.19
MnO	.30	.29	trace	trace	.05	trace	.18	.13	trace	trace
BaO	....	.25	....	....	....	....	trace	trace	....	....
LrO	....	.14	....	....	....	....	....	....	....	....
NiO	....	.17	....	....	....	....	....	....	....	....
Cu	....	.16	....	....	....	....	....	....	....	....
S	....	.54	....	....	....	....	.19	....	....	....
Total	100.53	99.79	99.03	99.71	99.31	98.30	98.76	99.93	99.35	100.29
Specific gravity	2.834		3.026	2.832	2.673	2.788	2.757	2.694	2.724	2.709

38 G. S. C., Vol. XIV, Part H, p. 83.
39 Quar. Jour. Geol. Soc. Lon., Vol. LIII, p. 56.

In the above table of results of analyses, No. 1 is from the basic edge of the northern range near Onaping, Mr. E. G. R. Ardagh, of the Chemical Department, School of Science, Toronto University, being the analyst. No. 2 is from the basic edge at the Creighton mine near the ore body, analyst Mr. M. T. Culbert of the School of Science. Nos. 3 and 4 are from the basic edge of the southern range near Blezard mine, analyst Dr. T. L. Walker. No. 5 is from a syenitic-looking specimen taken from near the middle of the Onaping section, analyst Mr. Ardagh. No. 6 is from near the middle of the Blezard-Whitson lake section, analyst Dr. Walker. No. 7 is from the acid edge of the Onaping section, the rock being greenish gray, analyst Mr. Ardagh. No. 8 is from near the acid edge on the north shore of Fairbank lake, the rock being dark green gray and somewhat schistose, analyst Mr. Ardagh. Nos. 9 and 10 are from points near the acid edge of the Blezard-Whitson lake section, Mr. C. B. Fox, chemist of the Hamilton Iron and Steel Company, being the analyst of No. 9, and Dr. Walker of No. 10.

The table is so arranged as to give first analyses from near the basic edge (Nos. 1, 2, 3 and 4), next analyses of specimens from near the middle of the eruptive (Nos. 5 and 6), and finally analyses from near the acid edge. The results disclose a larger amount of variation than might have been expected, especially on the basic side of the eruptive, the silica running frcm 49.90 to 60.15. It is possible, however, that No. 3 is not a typical example of the norite, since it contains so large an amount of ferrous oxide (13.54 per cent) as to suggest the presence of unusual amounts of iron ore, or of pyrrhotite. It is probable also that No. 2, from the Creighton mine, errs on the other side, containing more quartz, microcline and micropegmatite than the normal, though thin sections from other parts of the rock enclosing the Creighton ore body almost all show considerable amounts of these minerals.

The intermediate rocks from the middle of the eruptive seem to differ little from the examples taken from nearer the acid edge, having silica contents of 64.85 and 68.48 per cent., as compared with 61.93 to 69.27 per cent., or on the average 66.66 to 66.98.

An average of the first four analyses as representing the basic phase of the rock, and of the last six as representing the acid phase will give a fair idea of the amount of differentiation which has taken place in the cooling of the laccolithic sheet. It is possible, however, that in the case of No. 2 the norite absorbed some of the adjacent granitoid gneiss. At the actual contact of norite and gneiss there is sometimes a reaction rim a few inches wide of coarse pegmatite between the norite and the more acid rock. It may also be that No. 7, from the acid edge near Onaping, has become somewhat more basic than the normal by "overhand stoping" and absorption of the overlying tuff, since it is less acid than No. 5 from the middle of the section. However No. 2 may not more than counterbalance No. 3, which contains so large an amount of iron, and No. 7 will not greatly affect the average of the six examples of the acid phases.

	Basic Average.	Acid Average.	Average of whole eruptive.
	Per cent.	Per cent.	Per cent.
SiO_2	54.615	66.873	61.970
Al_2O_3	18.437	12.745	15.022
Fe_2O_3	.590	1.543	1.362
FeO	8.365	5.562	6.683
MgO	4.510	1.263	2.542
CaO	6.715	2.727	4.322
Na_2O	2.267	3.827	3.203
K_2O	1.417	2.787	2.239
H_2O	1.085	1.188	1.147
TiO_2	1.157	.502	.763
T_2O_5	.152	.202	.182
MnO	.122	.060	.065
Minor substances	.320	......	......
	99.752	99.279	99.500

In a general way about one-half of the southern edge of the laccolithic sheet is basic, while the basic portion of the northern range, including the Blue lake portion, is very much narrower, perhaps averaging not more than a quarter or even an eighth of the full width of the eruptive. An estimate of the relative areas of the basic and acid phases respectively gives about one part of basic rock to one and a half of acid rock. Accepting these proportions as approximately correct the average composition of the whole sheet is given in the third column above.

In this computation the pyrrhotite and chalcopyrite of the ore bodies have not been taken into account. Although 2,000,000 tons of ore have been mined and the amount of ore "in sight" may be reckoned at several millions more, it would be rash to attempt to estimate the total amount of sulphides originally contained by the magma, since we do not know how many millions of tons have been removed by erosion during the ages since the eruption, which took place not later than Cambrian times; nor do we know how much ore exists in the depths, as downwards continuations of known ore bodies or in ore bodies which do not reach the surface. However we can hardly assume that the sulphides existed to the amount of cubic miles, and the eruptive sheet still remaining after the vast period of erosion is estimated at 600 cubic miles, so that the sulphides in the total magma formed probably only a fraction of one per cent., and so are of relatively little account. Prof. Vogt speaks of the Sudbury gabbro as containing originally about 0.05 per cent., which may serve as a guess at the true proportion.[40]

According to the new classification of rocks the average composition of the basic, and acid phases work out as Harzose, and Adamellose. The norm for the basic and acid phases, and for the average rock is as follows:

		Basic.		Acid.		Average rock.	
Quartz		9.24		20.76		17.94	
Orthoclase		8.34		22.24		12.79	
Albite		19.39	51.92	31.06	37.73	27.25	47.27
Anorthite		32.53		6.67		20.02	
Diopside	$CaO \cdot SiO_2$	......		2.44	3.99	.22	.46
	$MgO \cdot SiO_2$	......		.70		.08	
	$FeO \cdot SiO_2$	......		.85		.16	
Hypersthene	$MgO \cdot SiO_2$	11.30	24.10	2.40	8.74	6.40	16.17
	$FeO \cdot SiO_2$	12.80		6.34		9.77	

Omitting unimportant ingredients, such as titanic iron ore, apatite and water, we see that the basic phase consists essentially of 52 per cent, of labradorite, 8 or 9 per cent. each of quartz and potash feldspar, and 24 per cent. of magnesia and iron silicates.

The rock of the more acid phase consists of 21 or 22 per cent. each of quartz and potash feldspar, 38 per cent. of oligoclase and 13 per cent. of magnesia-iron silicates.

The average of the whole eruptive, as represented in our analyses and weighted by taking two parts of acid to one of basic rock to correspond with the field relations, works out as Harzose of an acid kind.

The norm of the rocks worked out above corresponds fairly with the mode in the basic edge norite except that monoclinic augite replaces some hypersthene, and in the average acid phase of the eruptive hypersthene is largely replaced by hornblende.

Older Norite and Lavas

Associated with the basic edge for a number of miles along the southern nickel range, but evidently much older than the nickel eruptive, is a range of hills often high and rugged, which have been generally referred to and mapped as greenstones. Their extraordinary mixture of characters, including rocks such as norite, greenstone,

[40] Trans. Am. Inst. Min. Engineers, Vol. XXXI, 1901, Problems in the Geology of Ore Deposits, p. 129.

diorite porphyrite and amygdaloid, with some slaty graywacké undoubtedly of sedimentary origin, make it difficult to define the rocks as a whole. The frequent occurrence of "pillow structure," often with an amygdaloidal edge to the pillows, shows that at least a part of the series consists of lava flows.

The only rock which is at all fresh is the norite, which may now be described. Macroscopically and microscopically, it differs entirely from the nickel-bearing norite. It is usually very fine-grained and rather dark gray on fresh surfaces, and on weathered surfaces pale gray with numerous raised bands or narrow ridges of green, often in two or more directions, forming meshes. In some places the fine ground-mass contains hornblende crystals from a third to a half inch in diameter, which project from the weathered surface. Less often there are irregular white patches of about the same size along with the hornblende, giving a pale gray surface speckled with dark green and white blotches, suggesting a porphyrite. There are all transitions from the fresh gray norite through rocks half changed, to greenstones or hornblende porphyrites completely changed to green minerals, and it is probable from the field relations that part or all of the greenstones was originally norite.

Thin sections of the gray rock are usually surprisingly fresh in appearance except for narrow bands of green hornblende along minute fissures, and four minerals in small equi-dimensional grains or crowded crystals usually make up almost the whole of the rock, hypersthene or enstatite, a monoclinic augite, plagioclases (bytownite) and magnetite. Usually the two pyroxenes are very much alike, with strong outlines against the feldspars, pale brownish gray in color with faint greenish and reddish change of color or none at all, and a suggestion of crystal outline. Here as in so many other norites certain pleochroic sections, in general appearance exactly like the hypersthene, have a considerable angle of extinction from the cleavages or the edge of a prism, so that they are really monoclinic. It seems as if the hypersthene is merely a monoclinic pyroxene with 0° extinction angle, and with transitions to an unnamed monoclinic form of the same composition, but with large extinction angles. The rhombic variety of pyroxene is generally in largest amount, and the two pyroxenes make up as a rule more than half the section. The plagioclase is in short stout crystals with few twin planes, and in many cases the crystal form is fairly perfect. The magnetite makes up perhaps a twentieth of the whole rock.

Beside the ordinary even-textured variety of norite, or micro-norite, there are porphyritic ones in which a few large and generally elongated crystals of hypersthene or augite are embedded, and these may be poikilitic, including small grains of the feldspar. In other sections the porphyritic crystals are hornblende, green or brown, rough edged and always poikilitic, sometimes thickly crowded with clear feldspars. They may represent former augites, though this seems doubtful, since both minerals sometimes occur porphyritically in the same section. The magnetite is often in good crystal forms, the grains being relatively large. In most cases none of the minerals show a trace of weathering except as mentioned before, along thin seams where hornblende develops.

The rarer variety cf micro-norite, which has white patches like porphyritic feldspars, shows the same composition as the others, the white areas being formed of labradorite in the same short stout crystals as elsewhere, but without pyroxene or magnetite. There are occasionally sections wholly or almost wholly composed of the plagioclases, so that there are varieties of rock having the same general character which might be named norite, gabbro (where monoclinic pyroxene outweighs the rhombic), and anorthosite, with norite porphyrite or hornblendic norite and rarely biotite norite.

Some of the green rocks associated with the gray ones seem to be merely the same rock weathered, secondary hornblende replacing pyroxene, but the short equi-diametered plagioclases remaining. In other cases, however, the greenstones consist mainly of fibrous hornblende with some magnetite, and occasionally quartz, but with little or no feldspar; where one cannot assume that they have descended from the norite.

The "pillows," if large, are sometimes formed of characteristic micro-norite in the middle and hornblendic material on the outside, the supposed amygdules consisting of about equal parts of plagioclase and unstriated feldspar, with a little quartz. The contents hardly seem characteristic for an amygdule, but the bomb or pillow form and the development of the white spots only near the outside of the mass and not in the middle may be taken as proof that they are really surface eruptives.

The hornblende porphyrite associated with the older norite is probably derived from it, though this is not always certain. Those which have a fine-grained ground-mass with minute crystals of plagioclase mixed with hornblende and large poikilitic crystals of hornblende enclosed are probably derived from the porphyritic variety of norite. Others with hornblende alone or with quartz instead of feldspar can hardly be accounted for in this way.

In addition to the very fine-grained older norites in the complex, there are some coarse-grained ones, gray with dark green and sometimes white mottlings, which look very different from those described, but sections show the same minerals only differently arranged. The plagioclase is in minute grains almost as if crushed, but the pyroxene is always in large irregularly-shaped poikilitic crystals. As it is mainly monoclinic the rock must be called gabbro. The dark green patches are of secondary-looking hornblende.

The older norite or the micro-ncrite as it has been named in this report must have antedated the nickel eruptive by a very long time, since the sedimentary series 10,000 feet thick was piled up on them before the irruption of the laccolithic sheet; yet they are so uniformly confined to a comparatively narrow band along the southern nickel range and a few points on the northern range that one cannot resist the idea that they came from the same hearth. They are, however, much more basic than the nickel range rock, since pyroxene generally makes up half their bulk, magnetite is present in considerable amounts, and quartz or potash feldspars scarcely occur. They are not known to contain nickel except where an ore body lies against them sending small stringers into the older rock.

An analysis of a typical specimen from near Murray mine has been made by Mr. J. A. Horton of the Chemical Department, School of Science, Toronto, with the following results:

	Per cent.
SiO_2	46.69
Al_2O_3	14.23
Fe_2O_3	2.00
FeO	12.82
MnO	.11
MgO	8.15
CaO	13.32
Na_2O	.98
P_2O_5	.19
TiO_2	1.28
Moisture	.08
Sulphur	.12
	99.97
Specific gravity	3.24

This corresponds normally to the following mineral composition:

	Per cent.
Bytownite	42.57
Diopside	25.73
Hypersthene	20.76
Olivine	5.34
Titanic Iron Ore	4.98
Apatite	.34
Pyrite	.27

The mode of the rock does not differ greatly from the norm. No olivine has been recognized, but a small amount may really be present, as the rock is very fine-grained, and part of what has been taken for augite is not unlike olivine in appearance. If I

have worked it out correctly by the new system, it is a percalcic rock of the order Gallare, under the subclass Salfemone of the class Salfemane; and may be named Kedabekase.

It is curious that the sulphide commonly found in the older norite is pyrite and not pyrrhotite. In composition this rock comes much closer to the European norites with which pyrrhotite is associated than does the acid norite of the Sudbury nickel eruptive.[41]

NORITE OF THE INTERIOR BASIN

While the characteristic norite of the nickel eruptive is confined to the basic portion of the sheet, it is known that in one place at least norite of a somewhat different kind occurs near the acid edge, penetrating the basal conglomerate. At the southwest end of Trout lake in Bowell township, near a small zincblende deposit on location W D 252, a specimen of dark green rock weathering brown, taken as representing a part of the country rock, proves to consist of hypersthene, diallage and labradorite, the latter making less than half the section. There are also a very little interstitial quartz and still less micropegmatite. Some of the rather lath-shaped feldspars are of earlier crystallization than the hypersthene, but other parts are later. The feldspars, though decidedly fresh, are rather untransparent at the edges because of a brown coloration, the centres, which have a different extinction angle, being clear. The hypersthene seldom shows good crystals with elongated forms as it does in the basic edge norite. This norite was not distinguished from greenstone in the field, and no detailed work was done to define its boundaries or its relations to the nickel eruptive.

PERIDOTITE

Beside the comparatively basic older norites and greenstones in a few localities along the northern range still more basic rocks have been found as part of the country rock of ore bodies and are therefore probably older than the nickel eruptive. The freshest example is from test pits in Levack township about five miles north of Onaping, where a dark gray green fine-grained rock accompanies the ore. A thin section proves that the rock consists chiefly of olivine, more than half of which has been changed to serpentine and magnetite, which not only encloses the olivines but cuts across its crystals wherever fractures existed. There are in addition small quantities of augite and of brown biotite.

On location W D 155, in Bowell township, part of the rock beside the ore deposit is dark gray serpentine weathering rusty white. A thin section shows only a remnant of olivine and a few crystals of striated feldspar in the mass of serpentine and iron ores.

There is no direct evidence to show that the peridotites belong to the family of rocks connected with the nickel eruptive beyond the fact that they occur beside the basic edge.

LACCOLITHIC NORITE SOUTHEAST OF SUDBURY

An irregular mass of norite rising laccolithically to the east of Sudbury and extending several miles southwest from Ramsay lake to the north side of Kelly lake, has no apparent connection with the laccolithic sheet of the nickel-bearing rock and seems to be older than it, though this is not easy to prove positively, since it nowhere comes within three miles of the southern nickel range, with which it is roughly parallel. The last outcrop of the Copper Cliff offset, at Evans mine, is, however, only a quarter of a mile from its northwest side near Kelly lake, but there is so little likeness between the band of rock here described and the norite rich in ore of the offset that they probably have no direct relationship.

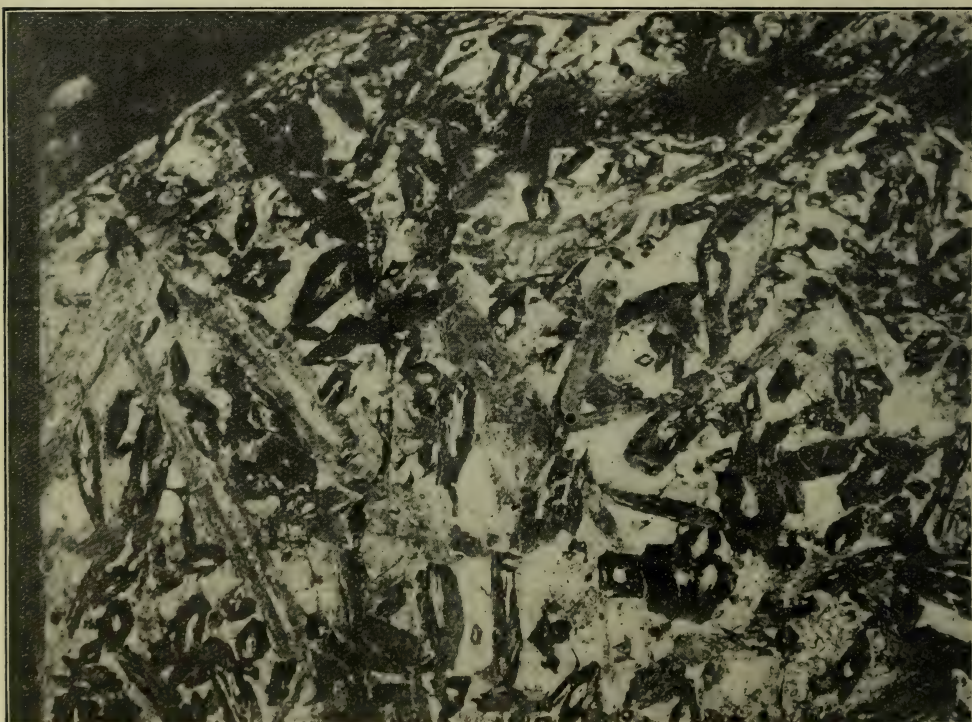
It may be that this irregular band, half a mile wide and more than seven miles long, is really the edge of a sheet, but if so there is no evidence of differentiation of the sheet into a lower, basic, edge and an upper, acid, edge as in the nickel eruptive.

41 Zirkel, Petrographie, Bd. II, pp. 790-1-2.

The rock is commonly medium to coarse-grained, greenish gray, and so far weathered as to contain no remnants even of the original pyroxene. Only one of my thin sections, from a point on the hill east of Sudbury, is fresh enough to show that the rock is really norite, though of a somewhat different type from that of the "basic edge." It is never dark gray in color, does not contain blue blebs of quartz nor large biotite scales, and is never spotted with ore, like the nickel-bearing norite, though a little pyrrhotite has been found in it.

The freshest section consists to the extent of about one-half of labradorite, the pyroxenes making up the rest of the rock, diallage probably in slightly larger amounts, so that the rock should perhaps be called gabbro instead of norite. The rhombic pyroxene has an exceedingly pale dichroism, so that it is enstatite rather than hypersthene. There is very little magnetite, no apatite was observed, and quartz is almost absent. The sections of weathered rock have the pyroxene completely changed to pale green hornblende or sometimes partly to chlorite. A little quartz is occasionally found in interstices and rarely also micropegmatite.

The most interesting feature of this band of norite or gabbro is the immense white segregations which run irregularly along the hill tops and perhaps represent the acid phase of the nickel eruptive though in much smaller proportion. Similar but much



Hill east of Sudbury; concretionary structure in gabbro.

smaller formations are found along the basic edge of the main nickel range near Elsie and Murray mines, but there the differentiation is much less complete, never resulting in large masses of solid quartz in the middle.

Very good illustrations of these segregations are found on the hills just east of Sudbury and at the quartz mine south of Copper Cliff, from which already hundreds of tons of quartz have been taken. At the latter point the width of the segregations is about 100 yards and the somewhat discontinuous row of white outcrops is at least half a mile long.

The ordinary gray green gabbro passes rapidly into a darker green band much coarser in texture and containing little feldspar. The cleavages of the hornblende are often curved or twisted. Then there is a band of mixed hornblende and white feldspar in very large crystals, the hornblende often as prisms several inches long, the centre of the prism being filled with white feldspar. Next comes a considerable width of white binary granite, very large-grained, and also graphic granite, the quartz often in larger quantity than the feldspar. At the centre of the large segregations there may be fifty feet of almost pure glassy quartz. With the inner white parts of the mass there are frequently sulphides, pyrrhotite especially, but never in workable amounts.

Thin sections representative of these exceedingly coarse rocks are hard to make, since a single section may be all of one material. The hornblende is secondary-looking and rather pale green, not far from actinolite; the white minerals are plagioclase (oligoclase towards albite), orthoclase (or at least an unstriated feldspar), and quartz, the latter often in comparatively wide bands in the feldspar, causing the graphic structure. A very little muscovite occurs also. Different parts of the mass might be called amphibolite, malchite, acid anorthosite, binary granite, pegmatite and vein quartz.

These curious masses of coarse white minerals much richer in alkalies and silica than the average rock, but cut off from it by the ring of hornblende, probably represent the last remnants of the magma, accumulated and consolidated in the centre of the band after the outer parts had already taken shape; resembling in origin the coarse pegmatite dikes which end an eruption of deep seated granite, but without the outlet into fissures which the hot pegmatite solution finds for itself.

It is possible, however, that the apparent segregations are really large masses of quartzite or arkose incompletely digested by the gabbro.

GRANITES ASSOCIATED WITH THE NICKEL ERUPTIVE

Beside the granite and granitoid gneiss of the Laurentian, which are much older than the sheet of nickel eruptive and underlie it, there are coarse and medium-grained granite and granitoid gneiss, probably not very different in age from the nickel eruptive, but sometimes a little older and sometimes younger. As they occur in bands parallel to the southern nickel range and at no great distance from it, they may be supposed to have some connection with the nickel rock in origin, perhaps having segregated from the same magma before or after the magma of the laccolithic sheet reached its present position. The coarse-textured granitoid gneiss, often porphyritic, is in my opinion generally older than the nickel rock, but is younger than the micro-norite described above, since it has swept off masses of greenstone and green schist supposed to be derived from them.

The granitoid gneisses are best shown along the railway between North Star and Creighton mines, where they are coarse in texture with porphyritic flesh-colored orthoclases sometimes an inch in length crowded together with an equal amount of gray finer-grained ground-mass. Thin sections show an ordinary hornblende granite, consisting of quartz, orthoclase, microperthite, a little plagioclase, much hornblende and a little biotite. There is no micropegmatite in the sections studied. The porphyritic crystals are orthoclase, sometimes a little crushed at the edges. While micropegmatite seems absent from the normal rock there is a reaction rim an inch or two wide at the contact of norite with this granite in the Creighton open pit, which shows coarse pegmatitic intergrowths, forming crystals often more than an inch in diameter. As the norite at this mine contains appreciable amounts of micropegmatite, such a reaction rim is not surprising.

The rock just described passes by gradations into a darker gray rock with much more hornblende and less quartz, which should be called syenite.

Near Copper Cliff there is a porphyritic granitoid gneiss, paler in color and with smaller phenocrysts, which has been used as building stone in the town. It contains more quartz than the Creighton rock, and little or no hornblende, but biotite in small quantities. The feldspar is mainly microcline, but there is some orthoclase and oligoclase.

Similar gneiss has been collected from other places, but has not been studied in thin sections.

While the coarse granitic rocks are generally older than the norite, there is a medium-grained flesh-red granite covering considerable areas from near Elsie to Little Stobie, which is undoubtedly later in age, since it penetrates the edge of the norite at Murray mine. The rock is normal granite with much quartz and microcline, some microperthite and orthoclase, a little oligoclase, a small amount of biotite and still less muscovite. No micropegmatite was observed.

As this granite occurs close to both the nickel eruptive and the older norite it is probably a later member of the same family of rocks. An analysis by Mr. James Horton gives the following results:

	Per cent.
SiO_2	75.62
Al_2O_3	11.02
Fe_2O_3	3.17
FeO	1.29
MuO	.12
MnO	.26
CaO	.58
K_2O	5.33
Na_2O	3.11
TiO_2	.16
H_2O	.10
	100.76

Specific gravity, 2.59.

It is evidently a quite acid granite. Calculating the normal minerals for the chemical composition we find the following:

	Per cent.
Quartz	35.76
Orthoclase	31.14
Albite	26.20
Anorthite	3.06
Hypersthene	.62
Ferric oxide	.63

Probably part of the sodium belongs to the orthoclase, since the extinction angles of the plagioclase correspond to oligoclase and not to albite. According to the new system the rock may be called Omeoze, a dopotassic, peralkalic rock belonging to the order Britannare, but near the boundary of Columbare. It is the most acid of the rocks supposed to have sprung from the hearth of the nickel-bearing eruptive.

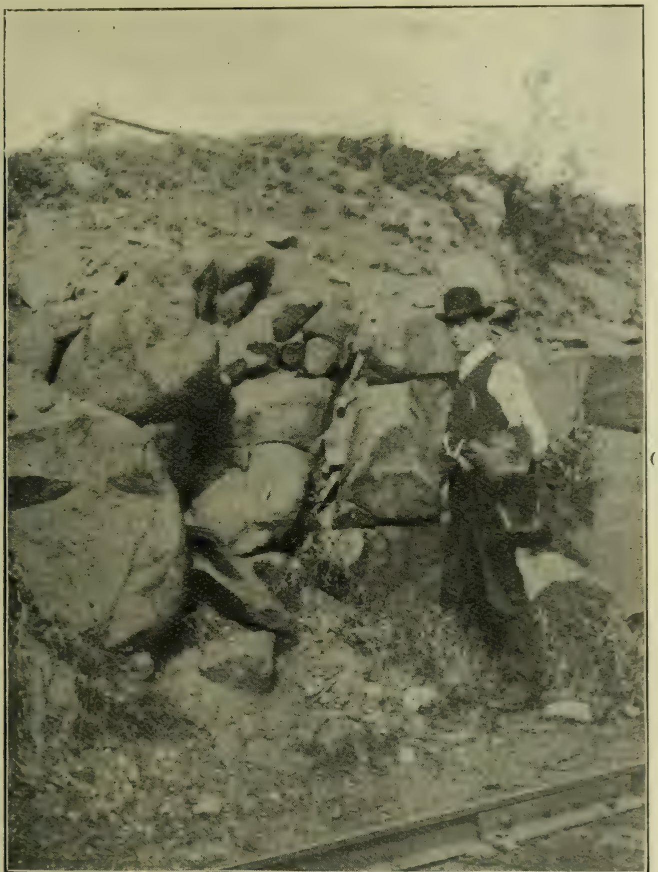
GRANITE FROM DIKES

Several dikes of granite near Copper Cliff are evidently later than the norite, since they cut the nickel rock. They are gray, and consist mainly of quartz, orthoclase and oligoclase with some biotite and muscovite. A few masses of flesh-colored granite enclosed in norite, probably as dikes, northwest of Murray mine and of Little Stobie are of much the same character.

As small dikes in larger dikes of diabase, a grayish fine-grained granite forms the latest rock in the region, perhaps a last upflow of the original magma from which the eruptives described above had their origin. It consists essentially of quartz and orthoclase with a little oligoclase, the only dark mineral being biotite, which in two out of three sections is changed to chlorite. Except for the slightly porphyritic habit of a few feldspar crystals, there is little to mark this as a dike rock.

It is surprising to find all the granites associated with the nickel eruptive, representing as they do at least three ages, so very different from the acid edge of the eruptive itself. The latter almost always consists to the extent of more than one-half of micropegmatite, the feldspar being orthoclase with a larger amount of plagioclase; while the other granitic rocks never have a micropegmatitic structure except for an inch

or two in contact with the norite at a few of the mines. The granites have always a much larger amount of potash than of soda feldspars also, which makes another point of contrast. It is clear that they are not direct derivatives of the nickel eruptive magma, though they probably originated in the same source at earlier or later times.



Granite dike in diabase, west of Sudbury.

DIABASE

Except for the few small dikes of granite which cut them, diabase is the youngest rocks of the Sudbury district, cutting all the others as dikes. The dikes are numerous and generally contain very fresh material, which, however, very readily weathers into spheroidal forms. Professor Walker[42] and Dr. Barlow[43] have paid considerable attention to these handsome rocks, the former having analysed a specimen, and the latter having mapped a number of the dikes near Sudbury. Some of the dikes are very porphyritic. containing tabular plagioclase crystals of all sizes up to a square inch in area, but other dikes near by are not porphyritic. The larger dikes are very fine-grained at the edge and gradually become coarse-grained in the middle; and where the dikes cut ore, as at the Creighton mine, their edges may be chilled so far as to become glassy. In the ore there are curious boulder-like projections from the dikes, as if occupying rounded cavities in connection with the fissure filled by the diabase.

[42] Quar. Jour. Geol. Soc. Vol. LIII, pp. 62-65.
[43] Geol. Sur. Can. Vols. XIV, Part H, pp. 90-92.

There are probably diabase dikes of two ages in the region, one the exceedingly fresh rock just referred to, and a less numerous class, now greatly weathered, the porphyritic dikes belonging to the first class. The coarser parts of the dikes consist of plagioclase (labradorite), at least one-half, lilac or reddish brown augite a quarter, olivine one-fifth, and biotite, magnetite and apatite for the rest. The plagioclase is distinctly ophitic and often imbedded in the augite or even the olivine. The order of succession is magnetite and apatite, olivine with plagioclase partly overlapping it, plagioclase, augite; all the other minerals being sometimes enclosed in the last mineral.

In smaller dikes or near the edge of larger ones, plate-like phenocrysts of plagioclase are enclosed in a fine-grained ophitic ground-mass of the minerals named above; and at the edge of dikes against ore the porphyritic crystals of plagioclase and also of augite are contained in a glassy basis pierced in every direction by minute plagioclases. Many of the larger laths of the second crop of plagioclase have narrow inclusions of glass in the centre.

The type just described is best displayed at Creighton mine, but the coarser-grained varieties are widely spread in the region.

The dikes which are thought to be older may occur with the other ones, but it has not been proved that the others cut them. They are not porphyritic, are less ophitic than the fresh diabases, and the augite and olivine, if any of the latter mineral existed, are completely changed to secondary hornblende, magnetite and leucoxene. There is present also a little quartz, which is entirely absent from the fresher rock.

The results of an analysis of fresh olivine diabase from a dike near Murray mine is given as follows by Prof. Walker:

	Per cent.
SiO_2	47.22
Al_2O_3	16.52
Fe_2O_3	3.32
FeO	12.40
MgO	3.33
CaO	9.61
Na_2O	3.40
K_2O	.67
H_2O	.30
TiO_2	3.62
P_2O_5	.33
MnO	.04
BaO	.01
CuO	trace.
NiO	.0275
CoO	.0055
Total	100.803
Specific gravity	3.01

The analysis shows that the rock is very basic, much more so than the nickel-bearing norite, but that it contains only a little nickel. The large amount of titanium accounts for the peculiar lilac or reddish color of the augite.

Whether the diabase is to be looked on as almost the last member of the succession of segregations from the great nickel-bearing magma is not certain. Dr. Barlow suggests that the weathered diabase containing some quartz near Copper Cliff is connected with the norite of the eruptive. These dikes are undoubtedly later than the norite, which they cut sharply across, but they may belong to the succession. The fresh olivine diabase seems to me more probably distinct from the main hearth, since very similar olivine diabase porphyrite occurs as dikes at various places to the west, e.g. north of Lake Superior, where no connection with any nickel eruptive can be assumed. Exactly why such similar dike rocks should have been erupted from point to point along a distance of hundreds of miles is hard to explain. The western dikes are generally supposed to have a connection with volcanic activity during Keweenawan times, when they penetrated the Animikie and lower rocks, and it is not improbable that the fresh Sudbury olivine diabases are of the same age and conected with similar phenomena.

It should be mentioned that olivine diabase is not confined to well defined dikes in the Sudbury region, though that is its commonest mode of occurrence. On the south half as lot 11, con. VI, of Denison township an irregular mass of fresh olivine diabase spreads out as hills to the width of 1,200 feet, cutting across the Worthington nickel-bearing offset, forming a boss instead of a dike, or possibly resembling on a small scale the Logan sills of olivine diabase in the Animikie near Port Arthur.

Petrography of the Sedimentary Rocks

LOWER HURONIAN SEDIMENTS

As mentioned previously the oldest rocks in the region are sediments belonging to the iron formation, which occur a short distance north of the northern nickel range near Clear lake in the northern part of Wisner township, near the outlet of Wahnapitae river in the lake of the same name, and to a much larger extent in Hutton and other townships several miles to the northward. These sedimentary rocks, consisting of granular silica or jasper interbanded with magnetite, are interfolded with greenstones and green schists. As they have been described in former reports of the Bureau of Mines, they will not be further discussed here except to state that they belong to the upper part of the Keewatin of the latest classification (Lower Huronian of previous reports of the Bureau).[44]

The oldest rocks in contact with the nickel ranges belong to the next formation above, now called the Lower Huronian, including arkose, quartzite, graywacké and slate, older than the Laurentian and underlying the nickel-bearing sheet. Their petrography has been touched on by several writers, Prof. T. G. Bonney[45] and Prof. G. H. Williams[46] being probably the earliest, followed by Prof. Walker in his Inaugural Dissertation (1897), the present writer in various reports of the Bureau of Mines, and Dr. Barlow in his report on the Sudbury mining district in 1904.

Bonney is greatly puzzled with these rocks, which he hurriedly visited soon after the Canadian Pacific railway reached the locality. In reality it is clear from his account that he has confused two or three distinct series in his work, and naturally had difficulty in harmonizing matters. He is inclined to think the quartzitic rocks sedimentary, but finds them so completely re-crystallized that they might be granite. He refers to the numerous crush breccias, but seems not to distinguish them from true conglomerates.

Williams describes a number of sections of quartzite or arkose near Copper Cliff and elsewhere, but hesitates whether to call them clastics or felsites, which is not surprising when his material consisted only of small specimens with no assistance from the field relations.

Dr. Barlow gives a good description of the microscopic characters of these rocks and admits that some of them are altered sandstones, but thinks the larger part were volcanic ash.

In my own opinion the major part of them are water-formed sediments, sandstone or arkose, largely re-crystallized, the materials being of eruptive origin, though not as ash, but as derived from granitic rocks by ordinary clastic methods.

Part of these rocks are pale flesh-colored and very fine-grained, having the look of felsite and presenting little evidence of bedding; though they are associated with beautifully stratified rocks and seem at times to pass by transitions into them. The rocks near Copper Cliff, which have sometimes been taken for felsite or syenite, are good examples of the variety showing hardly any bedding.

Sections consist of completely interlocking grains of quartz, orthoclase, microcline and a little plagioclase. There is seldom a hint of waterworn fragments, though occasionally the centre of a grain is a little cloudy. Regeneration has gone to the extreme,

44 Bur. Mines, Ont., 1903, pp. 318-321; also 1904, pp. 216-221.
45 Jour. Geol. Soc., London, Vol. 44, 1888, pp. 32-44.
46 Geol. Sur. Can., 1890, Appendix I, Part F, pp. 65-82.

and sections have quite the look of a fine-grained granite. There are, however, small dirty particles that do not seem to belong to a granitic rock. Occasionally large grains are bedded in the finer matrix with a suggestion of porphyritic structure, but they have no crystal outlines and are generally composite. In more highly metamorphosed parts long blades of green hornblende are developed, suggesting a variety of coarse syenite. Thin sections show the hornblende to be in very imperfectly formed crystals.

Specimens from points between Copper Cliff and Sudbury have more of a granular arrangement than near Copper Cliff, with fine debris between the grains, and are banded with finer and coarser layers and seem to contain minute rounded pebbles slightly different from the ground-mass. In addition to granules of quartz and feldspar, epidote and a considerable amount of biotite in minute scales can be determined.

Specimens taken from between Stobie and Blezard mines are formed of interlocking grains of quartz, orthoclase, a little microcline and a little oligoclase. There are a few shreds of hornblende also and a little of a dark mineral, probably magnetite.

On the whole these flesh-colored re-crystallized arkoses are very unsatisfactory rocks to study, and they pass into rocks so completely re-arranged that they might properly be called re-composed granites, applying the term used by Dr. Barlow.

On the other hand, there are transitions to pure quartzites in which feldspar is almost absent and only quartz and some scales of chlorite or biotite with a little indefinable dirty-looking material can be distinguished. Good examples of the last variety are found on the hill near Headquarters, in Garson township.

There are also transitions to graywacké, in which the muddy materials containing fragments of quartz and feldspar are to an extent re-crystallized into chlorite.

GRAYWACKE

The other main type of Lower Huronian sediments has been referred to in previous parts of this report as graywacké, though it includes also impure quartzite and slaty varieties, interbedded with the graywacké. These rocks are fine-grained, never flesh-colored, but always some tone of light or dark gray, and in hand specimens are often so uniform in appearance that they might be taken for a fine-grained basic eruptive. Weathered surfaces are lighter gray and disclose structures evidently water-formed. On glaciated parts the more quartzose layers retain their smoothness, but the softer layers of a somewhat slaty character may be deeply attacked, bringing out sharply the bedding of the original sandstone, sometimes also cross bedding and cross sections of ripple marks. Still more common are the pseudomorphs after silicates rich in alumina, such as staurolite, whose outlines are often very distinct and of all dimensions from a grain of rice, in the so-called "rice rock," to forms five inches long. In many cases the pseudomorphs are pale gray or even white and stand out strikingly from the darker tone of the rock. Specially good examples of these pseudomorphs are found near Stobie and Frood mines.

Thin sections of these rocks show much the same minerals as are found in the arkose, but generally more quartz and always more of the micaceous minerals, sericite (or talc), chlorite, and biotite, as well as indefinable somewhat opaque materials. The shapes of the original sand grains are often distinct. In the same section there may be coarsely granular quartz with dusty materials between, and finer-grained layers of minute grains of quartz and feldspar confusedly mixed with sericite and chloritic scales.

The pseudomorphs are often of nearly pure finely granular quartz, but sometimes of sericite or chlorite. No trace has been found of the unchanged staurolite, though the six-sided cross sections and St. Andrew's cross twins are conclusive as to the original mineral. As this is a mineral usually formed in slaty rocks near an eruptive contact, we may suppose that the slaty graywacké was locally metamorphosed by adjoining gabbro or norite masses, or perhaps in some cases by bands of granite.

Parallel with the graywacké having porphyritic pseudomorphs after staurolite near Frood and Stobie mines is a band of graywacké of a coarser texture, seemingly made

of obscure fragments of rock with concretions of paler color scattered through it, and containing large oval or eye and eyebrow-like masses of quartzite. There seem to be gradations between the apparent concretions and the larger quartzite masses. The latter are as well rounded as pebbles, but generally have a concave hemispherical slice shifted half an inch away from them, in cross section showing a large oval eye and crescent-shaped eyebrow. The cause of these curious shapes is not known.

Thin sections of the graywacké consist of quartz, orthoclase, microperthite, much biotite, and some epidote, mostly as completely interlocking crystals. The vague pebble-like or concretionary forms seen on weathered surfaces differ from the matrix only in a slightly different size of the grains and a less amount of biotite. The "eyes" are of quartzite with sharp margins.

A section of graywacké with rather distinct concretions but no "eyes," consists of the same minerals, the vaguely edged concretions having finer-grained materials and less of the dark minerals.

This rather narrow band of rocks has more of the feldspars than the graywacké described before, and is somewhat more completely re-crystallized, perhaps because nearer to eruptive rocks. Whether they are related to the singular hornblendic rocks containing crowded pea or bean-like white spots is uncertain; the different composition of the latter seems to set them apart. Beside the graywacké containing pseudomorphs or concretions there are near Frood mine mica schist and fine gray gneiss that probably present a still more completely re-arranged sediment, in which no water-formed structure remains. They consist of quartz with small amounts of clear feldspar, muscovite, biotite, chlorite and a little magnetite, the grains interlocking and showing no evidence of rounding by water.

GRAYWACKÉ CONGLOMERATE

Near Ramsay lake and at some other points in the region there is graywacké of a different kind from the rocks hitherto mentioned, with no marked stratification, but occasional angular or rounded pebbles or boulders, of more than one sort of rock, especially a reddish granite with very little in the way of dark minerals, and quartzite of different varieties. Near a small lake north of Ramsay lake fragments of the well stratified graywacké described on a former page occur in this rock near its margin, but they may have reached their place by faulting. On the shore of Ramsay lake a small promontory consists largely of a crowded conglomerate of the rocks mentioned with the stratified graywacké overlying it, as if a basal conglomerate had been overturned, but the evidence is not clear.

Since the graywacké conglomerate contains quartzite very like some of those which have been described as belonging to the Lower Huronian, it must be considered later in age, but the real relationships of the two rocks cannot be settled positively at present.

The ground-mass of the conglomerate is very dark gray on fresh surfaces, and shows small broken grains of quartz or of fine-grained quartzite. Thin sections contain fragments of quartz, angular or well rounded, of various sizes, embedded in a ground of much finer particles of quartz and perhaps feldspar with minute scales of brown biotite. The quartz grains are generally of a single crystal, though some are compound. Less numerous than the quartz grains are small fragments of plagioclase (oligoclase) and orthoclase or of felsite or quartzless porphyry. No marked amount of re-crystallization is to be seen except for the tiny scales of mica thickly scattered through the feldspar and felsite.

In macroscopic appearance the rock is more like boulder clay than anything else among modern rocks, and the microscopic characters do not conflict with this idea; but it might be rash to assume glacial action so early in the world's history.

THE TROUT LAKE CONGLOMERATE

The rock mapped as the Trout lake conglomerate, which is older than the nickel eruptive, but much younger than the previous sediments, lies between the acid edge

of the eruptive and the Onaping tuff, and in a sense is intermediate between them, the lower part being so changed by the presence of the eruptive during its long period of cooling as to resemble it closely, being distinguished often only by the presence of coarser-grained and redder patches with vague edges, which were pebbles or boulders of granite. In the upward direction the conglomerate may contain thin bands of white quartzite, gray chert or a green gray fine-grained rock; but finally passes into gray, fine-grained, crystalline-looking rock, containing angular or rounded fragments of chert and less often pebbles or boulders of granite and quartzite. This has no sharp boundaries separating it from the dark gray vitrophyre tuff.

The whole of the different phases mentioned above are considered to be ordinary water-formed sediments with little or no volcanic matter, but greatly modified by solutions coming from the laccolithic sheet beneath.

Where typically developed, but somewhat rolled out, the base of the conglomerate suggests certain Laurentian gneisses, being generally flesh-colored or gray with some parallelism of structure, the matrix like a fine-grained gneiss, the flattened boulders having a coarser grain and sometimes porphyritic feldspars. This phase soon passes into a fine-grained, somewhat speckled green gray rock with numerous flesh-colored or paler gray inclusions, the whole having the look of a variety of the Keewatin agglomerate of Rainy lake.

The less altered conglomerate has generally a darker gray fine-grained matrix and boulders or pebbles of lighter colored rocks with well defined outlines.

Thin sections of the matrix of the conglomerate near the acid edge of the eruptive have quite the appearance of a massive rock of the same composition as the acid edge itself, but with little or none of the micropegmatitic structure so characteristic of that rock. In fact every transition can be found between micropegmatitic grano-diorite of the typical acid edge and the matrix of the conglomerate, containing undoubted but vaguely edged granite boulders, so that the boundary between the eruptive and the sedimentary rock is no more sharp in thin sections than in the field.

At the very edge of the acid phase of the eruptive there are often small flesh-colored areas with a number of green epidote crystals and sometimes a space unfilled, and these patches are found also in the more altered phase of the conglomerate. Good instances of the transition are seen near Joe's lake. A specimen of gray fine-grained rock containing a pink granite pebble taken from near the eruptive edge at the outlet consists of quartz, orthoclase and much plagioclase in long strips with a little chlorite. The quartz is mostly granular, but partly in rude micropegmatitic intergrowth with feldspar, and in general appearance under the microscope the rock can be matched with specimens from the eruptive, and would be classed with it but for the enclosed granite pebbles.

A section from a sample taken 100 yards from the eruptive edge, containing a fine-grained granite pebble and numerous fragments of pale flesh-red and of green rocks, is much like the last one except that it is finer-grained and has a few large crystals of green epidote. At 180 yards the characteristic dark grayish tuff occurs, crowded with glass fragments.

A series of specimens taken from south of Moose lake shows more variety. The acid edge is coarse and reddish gray, with patches of red enclosing green epidote or small vugs with epidote crystals, and is made up to the extent of more than one-half of very elaborate micropegmatite about plagioclase crystals. Forty paces south there is undoubted conglomerate with granitic boulders in a matrix of the same minerals as the acid phase of the eruptive, but with only rough intergrowth of quartz and feldspar, and with numerous patches of greatly weathered orthoclase. Forty paces farther south there is a band of white quartzite or arkose about 60 feet wide, consisting of greatly crushed quartz and feldspar. One hundred and fifty paces from the edge the rock is fine-grained, bluish-gray, and contains pebbles of granite and quartzite with indistinct edges, one flesh-colored pebble enclosing green epidote. A thin section of the matrix might easily be taken for the acid eruptive, being made up of the same minerals, with micro-

pegmatite developed to various degrees, sometimes very elaborately, at others only hinted at by a rough intermixture of quartz with feldspar or by a tendency of the quartz to grow out with rounded projections into the other minerals.

The next specimen , 180 paces from the acid edge, is much like the one just described, but a thin section shows no micropegmatite, though the curious growth of the quartz in bunchy masses is more pronounced than in the former, and feldspar is present in less amount.

The next specimen is of a quite different kind, bluish gray and cherty in appearance with many angular fragments of whiter cherty fragments, proving in thin sections to consist of quartz with innumerable tiny crystals of epidote. This rock, 200 paces from the acid edge, is thought to belong to the overlying tuff rather than to the conglomerate.

A specimen of conglomerate near the acid edge at Onaping is much less granitic looking and in thin sections shows no resemblance to the acid phase of the eruptive, consisting of quartz and feldspar blending into one another with chlorite scales and often radiating bundles of actinolite. This matrix encloses grains of quartz and some angular fragments of a rock like very fine-grained quartzite.

A good series of specimens of the conglomerate comes from south of Windy lake, where the band is wide, and resembles that from Joe's lake, but thin sections of them have not been made. Another interesting collection comes from a small lake near the middle of Trill township, comprising arkose and a cherty rock as well as conglomerate. A section of the last rock is made up of quartz, orthoclase, epidote and chlorite, with embedded fragments of quartzite, and does not resemble the acid eruptive.

Specimens of schistose conglomerate from the north shore of Whitewater lake have numerous pebbles of granite and quartzite, and a few of green schist in a fine-grained gneissoid ground-mass, too much sheared or squeezed to show original structures.

In a general way it may be stated that the Trout lake conglomerate has been greatly metamorphosed near the acid edge of the nickel eruptive, the process often going so far that the matrix, probably arkose in the beginning, is completely re-crystallized into a rock containng the minerals of the acid eruptive, even the micropegmatite structure being produced to some extent. The enclosed pebbles, being of crystalline rock such as granite and quartzite, have undergone less change, but their boundaries have been blended with the matrix to a considerable degree.

THE ONAPING TUFF

No rock in the Sudbury district except the nickel-bearing eruptive itself has attracted more attention than the tuff (or vitrophyre tuff) which runs as a range of hills round the outer edge of the basin with the conglomerate between it and the acid edge of the eruptive. This rock appears to have been noticed first by Prof. Bonney at the High falls of the Onaping, being described as a "fragmental rock like a volcanic ash. . . . . The finer matrix is almost opaque, a very dark dust; the smaller fragments are quartz (not abundant) and altered feldspar or devitrified glass. The larger have probably been a moderately acid glass, sometimes vesicular. . . . . The zonal arrangement of some of the evitrification-structures suggests that the changes have taken place *in situ*."[47]

Dr. Bell was struck with the rock and sent specimens to Prof. G. H. Williams, who gave an excellent description of their microscopic characters, with an illustration, naming the rock vitrophyre tuff.[48] He found the ingredients to be mainly glass fragments, now largey silicified. The present writer, having a larger amount of material, added a number of substances, largely clastic, to the list contained by the tuff;[49] and Prof. Walker and Dr. Barlow have described them in their reports on the region, the latter quoting Williams' account of them.[50]

47 Quar. Jour. Geol. Soc., London, 1888, Vol. 44, p. 40.
48 Geol. Sur. Can., 1890, pp. 74 and 5 F.
49 Bur. Mines, 1903, p. 291; also Can. Rec. Sc., 1893, p. 344.
50 Geol. Sur. Can., 1904, p. 73 H

The rock is very dark gray and compact with many specks and angular fragments of paler material and also of pyrrhotite. It weathers to brownish and whitish surfaces which are very rough, since some of the glass fragments weather out sooner than the matrix. Here and there pebbles or boulders of red granite and of gray quartzite occur in the tuff, and also blocks of a grayish cherty rock, which takes a streak from steel, but which sometimes weathers in a way unlike chert. No bedding has been observed by me, though the well rounded pebbles enclosed suggest strongly that the ash was deposited in a body of water. Prof. Walker has noticed stratification, however, near Whitson lake.

The rock breaks with a conchoidal fracture and is very hard and brittle, many of the included fragments being changed to chalcedony, and as Bonney notices, having occasionally a concentric arrangement due to water action since the rock was formed.

In thin sections angular fragments of different sizes are crowded together with a small amount of almost opaque material between. The sharp-edged splinters and fragments of glass are very striking, some showing fluidal structure, others apparently pumice or slaggy glass with round or oval inclusions now filled with green serpentine, while the clear parts are chalcedony. Some of the fragments consist entirely of serpentine, others entirely of chalcedony, and still others of chalcedony on the outside and serpentine in the middle. There are also fragments with chalcedony on the outside and crowded epidote crystals in the middle, the latter mineral occurring also as radiating forms in round masses like tiny amygdules. Beside the glass sherds, now completely devitrified, there are fragments of quartz and less often of feldspar, both striated and unstriated, some fibrous hornblende, and also calcite or some other carbonate, either as single individuals or as composite masses. The carbonates may be products of re-arrangement of some volcanic rock, and all the other substances mentioned may be of eruptive origin; but the small pebbles of quartzite and of fine-grained granite must be clastic materials, and the same is true of the large masses of the same rocks enclosed as rounded boulders in the tuff. The source of the blocks of cherty rock in the tuff is not clear unless they come from cherty developments near the top of the next lower series, the Trout lake conglomerate.

The best examples of vitrophyre tuff in my collection come from Onaping, near Trout lake in Bowell township, and the southern part of Wisner township. Good examples are found also north of Whitson lake, where Prof. Walker obtained the example which he analyzed with the following results:[51]

SiO_2	59.93
Al_2O_3	12.12
FeO	10.56
MgO	5.19
CaO	4.49
Na_2O	3.80
K_2O	.97
MnO	trace
Loss by ignition	1.57
Total	98.63

A partial analysis of the rock from Onaping, by Dr. Hoffman gives 60.23 per cent. of silica, which does not differ greatly from 59.93.

The dark gray or black variety of tuff described above passes downwards into a paler gray rock with lighter fragments scattered through it, the lighter portions sometimes containing darker streaks and spots. The edges of the included fragments are not quite as sharp as in the variety described above, but in the earlier stages the main difference to tbe seen under the microscope is the loss of the dark coloring of the matrix and the disappearance of the smaller chips of glass, the larger one still showing their flow structure, etc., and consisting of serpentine and chalcedony.

Still nearer the conglomerate, at Moose lake, sections of the gray rock show fewer structures which can be referred to devitrified glass fragments, and the whole rock is

[51] Quar. Jour Geol. Soc., Vol. 53, p. 45.

changed to chalcedony or a mosaic of crystalline quartz with much epidote and some chlorite or mica. Evidently the change is due to proximity of the acid edge of the nickel eruptive, which at this stage is only a few hundred or a thousand feet away. Very similar changes are seen at Onaping but no thin sections of them have been studied.

On the opposite side the vitrophyre tuff passes into slaty phases, black, with paler and also darker flakes, probably representing flattened fragments of some kind, perhaps volcanic. Occasionally there is a small grain of quartzite also. The slaty cleavage, while distinct, gives rather rough surfaces unlike those of the Onwatin slate into which this rock grades.

Thin sections show plainly that the slaty rock is related to the tuff, since there is a black, almost opaque ground with many light-colored angular fragments of glass changed to serpentine and chalcedony, sometimes perlitic, but there are many specks and larger areas of carbonates, and pyrite crystals, often with chalcedony radiating from them. The black coloring matter seems to be carbon as in the slate, and is confined to rounded flakes too opaque for determination. It is surprising to see so little crushing or stretching of the glass sherds in a rock showing such marked slaty cleavage.

In general the slaty tuff contains more of the ordinary clastic sedimentary material than the harder variety, such as grains of quartz and of a dolomitic rock, both of which are present in large numbers, as well as the carbonaceous flakes mentioned above. In fact, the glass fragments form less than half the rock, which is really a transition toward the slate.

THE ONWATIN SLATE

The black slate into which the slaty variety of tuff merges is free from visible fragments of any kind, compact in appearance and very cleavable, the cleavages crossing the stratification, as shown by slight dfferences in texture. The surface weathers gray owing to the slow oxidation of the carbon which gives the black color to the fresh rock. Near Vermilion lake there has been a great deal of faulting and slickensiding in places, and here the polished surfaces have the feeling of graphite and soil the fingers; the color, however, is darker than that of graphite. Thin slivers turn pale gray when held in a flame and lose several per cent. of their weight, while a specimen analysed by Dr. Ellis contained 6.8 per cent. of carbon. If the carbon is estimated at 5 per cent. of the Onwatin slate, which has a thickness of 3,700 feet, the total amount is 460,000,000 tons per square mile. The area of slate is about 140 square miles, and it would be a very respectable coal field which should contain as much fuel as this sheet of slate. It is probable that the carbonaceous matter was originally of a bituminous kind, since the vein of anthraxolite mentioned in a previous chapter could only have been formed in that way.

Thin sections are not very satisfactory, since they are untransparent unless exceedingly thin. The minerals recognized are quartz, sericite, chlorite and the dark colored, opaque, carbonaceous matter. No rutile needles have been observed.

THE CHELMSFORD SANDSTONE

Overlying the slate and to a slight extent interbedded with it is the gray sandstone or arkose rising as anticlinal hills in the centre of the basin. The rock is monotonous in color and in compositon, but in places contains a vast number of concretions from a few inches to three or four feet in longest diameter, with half that width. Except that the concretions weather more quickly than the surrounding rock and form oval, somewhat rusty depressions, the surfaces of the outcrops are singularly uniform. To the naked eye the composition of the rock is not evident, except that grains of quartz and sometimes feldspar cleavages and scales of mica are visible in the coarsest parts, where in rare instances small pebbles may occur. Thin seams of gray slate often part the sandstone beds, and may be squeezed into small folds and contortions. Slaty cleavage is marked in these finer seams and is often visible in the sandstone as well.

Thin sections of the slaty layers have the same composition as the Onwatin slate except for the lack of the dark carbonaceous substance. The sandstone consists largely of angular or rounded grains of quartz, though there are also decaying grains of orthoclase and microcline, and fresher ones of oligoclase, all imbedded in a dirty matrix, while biotite occurs sparingly. Thin sections of the concretions contain grains of the same minerals to the extent of about a third, the rest being a carbonate, which effervesces with cold acid, so that the concretions have the composition of impure limestone.

The longest axis of the concretions is always parallel to the strike, probably indicating compression, and the flattening of the concretions and the imperfect slaty cleavage must have been caused by the lateral pressure which produced the folds.

In previous maps of the region the four subdivisions of the sediments overlying the sheet of nickel eruptive have not been distinguished, and in some cases the conglomerate, which is schistose in many places, has been placed with the older Huronian sediments, the large amount of metamorphism which it has undergone near the acid edge of the eruptive giving it a much more ancient appearance than the other sediments. The widest part of the conglomerate, south of Gordon lake, was formerly included with the schistose edge of the nickel eruptive in the general Huronian color, which extended as a band from Gordon lake to the southwest end of lake Wahnapitae. The rest of the conglomerate was included with the tuff and part of the black slate under one color, the remainder of the slate and the sandstone having a separate color in the interior of the basin. Until our work of mapping the acid edge of the eruptive in detail was complete it was not known that the conglomerate formed a continuous, if sometimes narrow, belt round the other sedimentary rocks.

DEVELOPMENT OF THE NICKEL FIELD

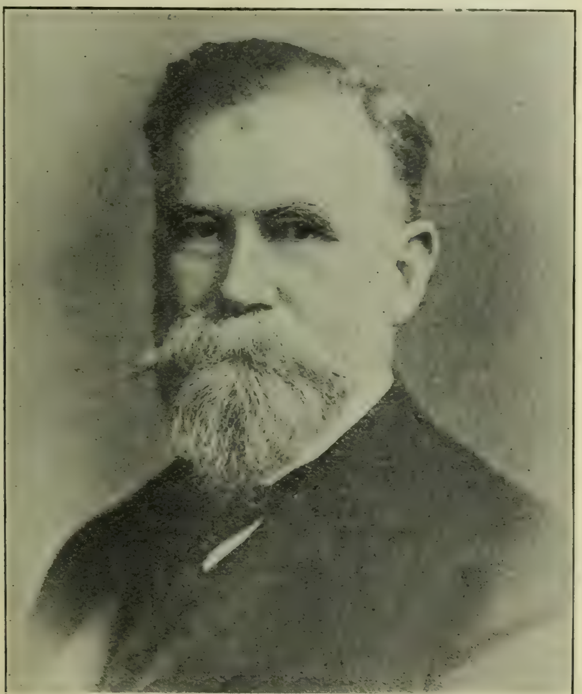
The literature bearing on the development of the Sudbury nickel mines has grown to be very voluminous. Most of the articles will be found referred to in previous reports of the Bureau of Mines; and a very complete resumé of the subject with its literature will be found in Dr. Barlow's report of 1904.[52] It will be unnecessary therefore to cover the whole of the ground in detail. It is intended to give here a brief, but fairly complete, account of the work done in the district, drawing on all sources of information, including personal accounts of participants in the work, not hitherto in print. Though the history of the region is comparatively short, since the first discovery leading to mining operations was made in 1884, there are doubtful points in regard to it and occasional conflicts between the statements of different authorities. The sources of information will be referred to as the chapter progresses, but the most important authorities relied on are Dr. Bell, Dr. Barlow, Dr. Peters and Capt. James McArthur. Most of the earlier statements are contained in the Report of the Royal Commission on the Mineral Resources of Ontario, the Annual Reports of the Bureau of Mines, and the Reports of the Geological Survey of Canada.

Though nickel and copper were discovered in the Sudbury district in 1856 by Murray, near what is now the Creighton mine, no importance was attached to this occurrence as long as the region was inaccessible by railway; and the history of mining in the district dates from the construction of the Canadian Pacific railway in 1883, when Dr. Howey found the deposit since called the Murray mine.[53] Early in the next year a cutting on the railway opened up the same deposit, and in the same year numerous other ore deposits were found, such as the Stobie, Copper Cliff, Evans and Blezard mines.

[52] Geol. Sur. Can., 1904, Part H, pp. 147, etc.
[53] Ibid., pp. 23 and 24.

These properties were all taken up for copper, the pyrrhotite being looked on as of no value, though it was suggested by Selwyn and other geologists that the mineral sometimes contained a little nickel.

It is surprising how many of the more important mines were found within the first year or two, but the fact that most of them were indicated by rusty hills of gossan no doubt accounts for the ease with which they were discovered. Even the Creighton mine, the latest of the large mines to be operated, was re-found in 1884. It is stated by Mr. Thomas Frood that the land surveyor, Mr. John McAree, who surveyed the township in 1884, noted the hill of gossan. Mr. Frood examined it in 1885 for other parties; and in 1886 it was secured by the Canadian Copper Company.



Dr. Robert Bell, Acting Director Geological Survey of Canada, Ottawa, Ont. Dr. Bell's paper on the Sudbury Mining District published in the Report of the Geological Survey for 1890-91 gave the results of three seasons' labor in the field by himself and assistants. It was accompanied by the first geological map of the region.

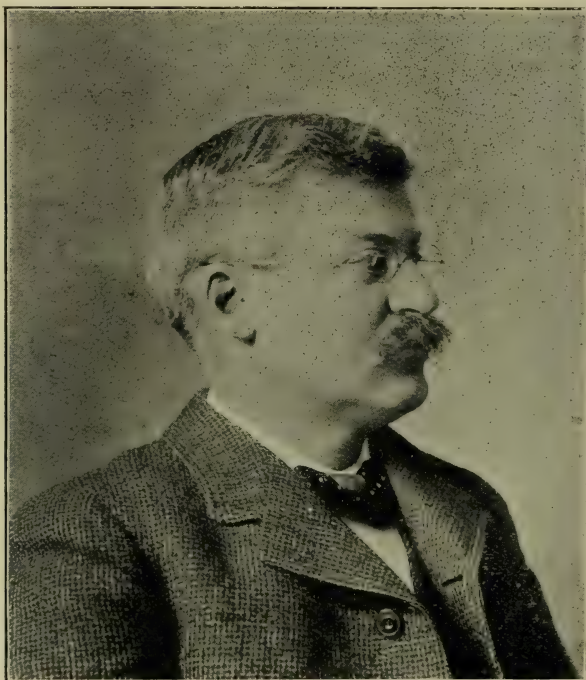
The work of indefatigable prospectors, such as Thomas Frood, Henry Ranger, William McVittie, A. McCharles and others deserves appreciative recognition in this connection. It is astonishing how quickly and accurately they grasped the important geological relationships, the association of ore bodies with the diorite, as the norite was then named. It may be doubted if many ore deposits of value, except those which have no outcrop upon the surface, have escaped their keen eyes.

Recognition must also be made of the great assistance furnished by the map of the region published by the Geological Survey in connection with their 1890-91 Report. This was naturally defective in various respects, since it simply embodied the rough results of reconnaissance work in a wild, bush-covered tract of rocky and swampy country. Drs. Bell and Barlow with their assistants furnished an excellent foundation for the pros-

pector, and wherever they mapped the diorite, the ground was very carefully scanned, thus aiding in the rapid development of the country from the mining standpoint.

Railways

Until there were means of communication no development of mines could take place, nothing more important than stripping and prospecting operations being possible; so that the development of the various mines was dependent on the building of branches from the new Canadian Pacific railway, which fortunately intersected the region. The Sault



Dr. Edward D. Peters, Dorchester, Mass. Dr. Peters is a well-known authority on modern processes of copper smelting, and was general manager of the Canadian Copper Company from June, 1888, to May, 1890.

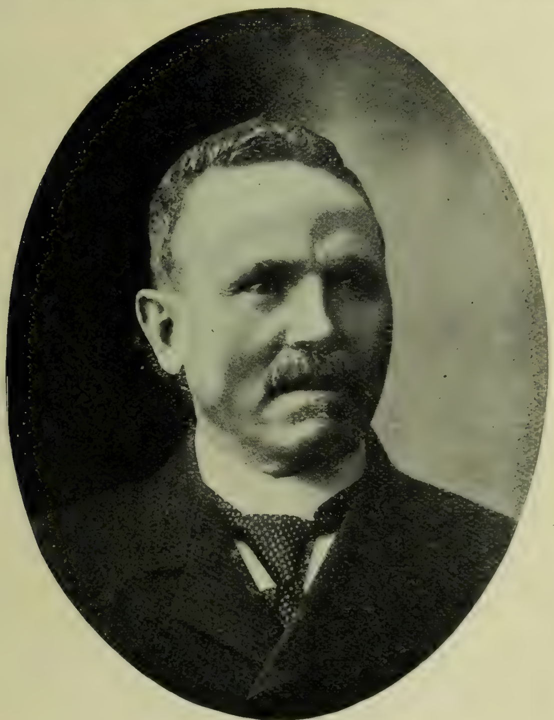
branch, running southwest from the junction at Sudbury, was easily connected with the Copper Cliff, Evans mine and other adjacent mines by short switches. The Stobie and Blezard required a branch five miles long to the north; and a short spur from Stobie provided an cutlet for the Frood, or No. 3, mine. The Murray mine was already on the line of the C. P. R. and required only a siding. These early mines were easily and cheaply put in connection with the railway; but before the Gertrude, Creighton and North Star mines could be operated it was necessary to build eleven miles of expensive track to the west of Sudbury, so that their development had to await the construction of a part of the Manitoulin and North Shore railway.

The northern nickel range is still without railway connections, and so cannot develop beyond the exploration stage.

The Canadian Copper Company

The history of the development of the Sudbury nickel region is very largely the history of the operations of the Canadian Copper Company, and one naturally takes this

up first. In 1885, before the company was organized, Mr. S. J. Ritchie was interested in the region and employed Mr. John D. Evans to survey several locations containing copper deposits. The Lady Macdonald mine, now mine No. 4, north of Lady Macdonald lake, was the first property on which work was done; but the Evans mine, south of what is now the Sault branch of the Canadian Pacific railway, near Copper Cliff, was soon after opened up. Early in 1886 the Canadian Copper Company was organized, with Mr. Ashman as superintendent, and Mr. Evans as engineer, and work began on the Copper Cliff mine in lot 12, con. II, of McKim township. Mr. Evans states that a road was cut through second growth woods from the Sault branch to the mine, which was then known as "The Buttes." On the 20th of May a cutting was started about half way up the slope, and as soon as the rock was reached rich ore was exposed. Then



Capt. James McArthur, for many years general manager Canadian Copper Company's smelting works, Copper Cliff.

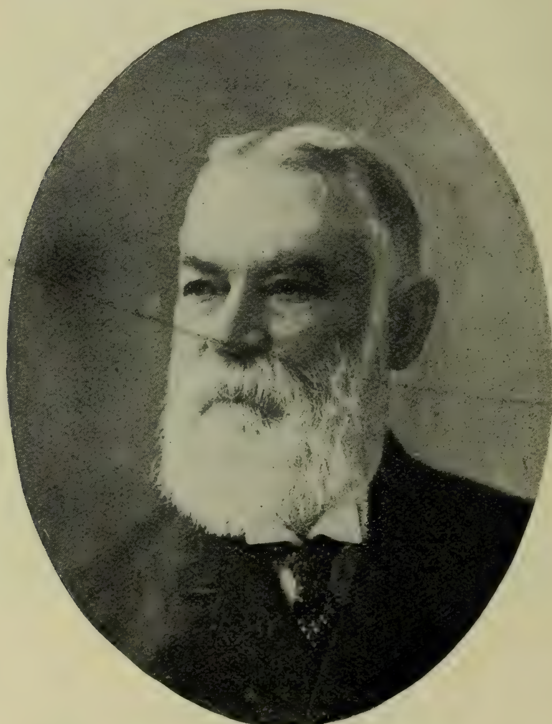
another horizontal cutting was made near the bottom of the slope reaching ore. Quarrying of ore then began from the nearly vertical outcrop, and continued uninterruptedly all the season, and 3,000 tons of ore were shipped at one time to New York for treatment. Up to this time nickel was not suspected, but in the treatment of this large lot of ore the nickel contents were discovered.

The first ore taken from the Copper Cliff is said to have contained 15 to 20 per cent. of copper, the ore having been enriched in copper above the water level, below which it gradually ran down to 8 or 10 per cent. of copper and nickel. It has proved to be the richest in copper of the large mines, though surpassed in percentage of nickel by the Creighton.

Two other mines, the Stobie and the Evans, were opened up later in 1886, and the three mines supplied most of the ore treated by the company until 1899, when the Evans was shut down. The Evans was worked mainly as an open pit, and with the exception of two idle years furnished ore from the beginning of operations till it was

closed. The Stobie mine, six miles to the northeast, in lot 5, con. I, of Blezard township, was much the largest producer in the district until the opening of the Creighton. It was worked, with the exception of one year, from 1886 to 1901, when it was closed down finally after producing more than 400,000 tons of ore. It was worked partly in open pits and partly by under ground mining. The ore, though not high grade, was less mixed with rock than usual, and was useful in fluxing the richer but more silicious ores of the other two mines, since it consisted largely of solid sulphides.

In 1898 two new mines became producers, No. 1, a short distance southwest of Copper Cliff, and No. 2, north of Copper Cliff; the former providing rich ore for a year, and the latter average ore in much large quantity. No. 2 has been worked mainly as an open pit, the opening giving a very impressive idea of the size and shape of an offset



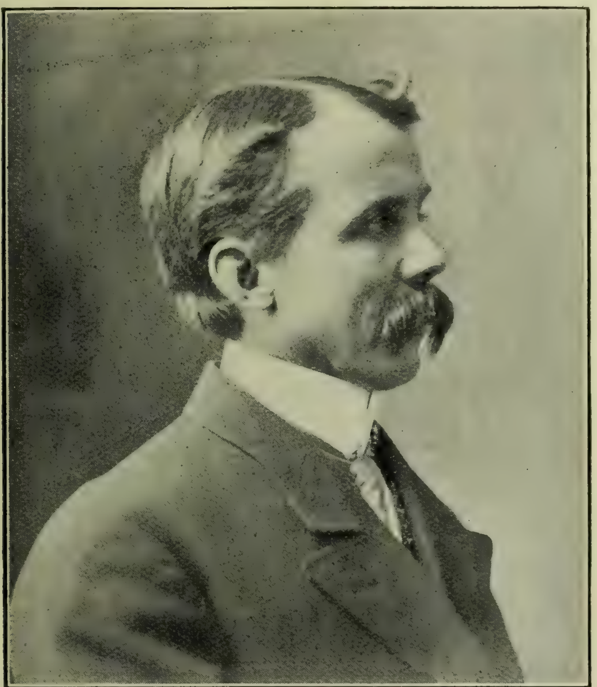
John D. Evans, Trenton, Ont. Mr. Evans was the Canadian Copper Company's first engineer, and as such assisted in opening up the Copper Cliff mine in 1886, 3,000 tons of ore being shipped to New York for treatment in that year; he had charge of constructing the first smelting works for that Company under Dr. E. Peters in 1888, the first shipment of matte being made therefrom 22nd March, 1889; and was general manager of the Company from May, 1890, to June, 1893.

ore body, but one or two levels have been opened up beneath the bottom of the pit by underground mining. When the Creighton came into full operation in 1903 this mine closed down.

In 1899 and two following years mines No. 4 and 5, northwest of No. 2, yielded some ore, and in 1900, No. 3, a mile southwest of the Stobie, often known as the Frood mine, began to supply considerable quantities of ore containing some intermixed rock, making it a useful flux for the solid pyrrhotite and chalcopyrite of the Creighton mine.

In a year or two it also was closed down. The ore from the Frood and Stobie mines was brought by rail to Copper Cliff, where it was mixed with the ore of other mines on the roast heaps.

In 1900 the great Creighton mine, six miles west of Copper Cliff, was stripped, and in the following year began to ship ore via the Manitoulin and North Shore railway to Copper Cliff. As the deposit is immense and can be worked cheaply as an open pit, while the ore averages higher in grade than any other in the district except the Copper Cliff, this mine has supplied almost the whole requirements of the company for the last three years, and the other mines have practically ceased operations. In spite of the richness of the Copper Cliff, which has produced some ore very high in nickel from its deepest workings, it has been closed down after reaching a depth of more than 1,000 feet.



A. E. Barlow, of the Geological Survey of Canada. Dr. Barlow's Report on the Nickel and Copper Deposits of the Sudbury Mining District, published in 1904 as Part H of the Geological Survey's Fourteenth annual volume is a full and adequate treatment of the subject.

During the summer of 1904 the Creighton produced about 18,000 tons of ore per month, and in total amount of ore it already far surpasses any other mine in the district or in the world. The closing of all the other mines is stated to be due to the ease of mining and richness of the Creighton, not to exhaustion of the ore bodies. If the Creighton becomes worked out in the process of years, there are supposed to be large reserves of ore still left in some of the other mines.

SMELTING OPERATIONS

The first smelting works was begun in July 1888, under the direction of the well known metallurgist, Dr. Peters, Mr. James McArthur and Mr. J. D. Evans being his assistants; and the furnace was blown in on the 22nd of December. This was the east smelter, which has now been out of operation for several years. The first shipment of matte was made on the 22nd March 1889.

In 1890 Dr. Peters was succeeded as manager by Mr. Woodbury, who retained the office only three months, when Mr. Evans was appointed manager and continued in that position till the end of June 1893. A bessemer plant was commenced in 1891, and completed in January 1892.

Mr. James McArthur succeeded Mr. Evans as manager in 1893, and continued in that position until 1902. During his regime the west smelter was erected near No. 2 mine in 1899, and the old, or east, smelter about three years later suspended operations. In 1900 a new method of changing the low to high-grade matte was adopted, and the Orford Copper Company put up the Ontario Smelting works, a short distance south-west of the Copper Cliff mine. In this plant the low-grade matte was roasted in Brown calciners, and then smelted a second time in a water jacket furnace, changing a 30 per cent. matte to one averaging 75 per cent. of nickel and copper, corresponding nearly to the former bessemer matte.

In April 1902, the Canadian Copper Company passed under the control of the International Nickel Company, organized to take over this and a number of other companies. Mr. A. P. Turner was made president of the Canadian Copper Company, and Mr. John Lawson, superintendent.

A. P. Turner, Copper Cliff, president Canadian Copper Company.

The second annual report of this company describes it as a consolidation of mines and smelters in the United States, Canada, Great Britain and New Caledonia, including the Canadian Copper Company, Orford Copper Company, Anglo-American Iron Company, Vermilion Mining Company, American Nickel Works, Nickel Corporation, Limited, and the Société Miniere Caledonienne. According to its statement of capital account in 1904 "the total assets of the company were $30,896,167, divided as follows: Property of constituent companies, $26,864,275; Ray Copper mine, $40,000; advances to New Caledonia companies, $348,363; inventories, $2,827,774; cash and accounts, $815,755; total assets, $30,896,167; common stock, $8,912,626; preferred stock, $8,912,626; stock of constituent companies, $55,643; first mortgage 5 per cent. bonds, $10,221,836; loans,

accounts, etc., $1,617,476; depreciation fund, $412,709; surplus account, $763,251; total, $30,896,167. The income account for the year shows the folowing receipts: Earnings from constituent companies, $936,471; other income, $29,754. Charges were: For general expenses, $112,185; interest, $512,938; total, $625,123. The net balance carried to surplus account amounted to $341,102."[54]

Following the combination just mentioned many changes took place in the work of the company. Mining was gradually limited to the Creighton mine, and experiments were made in regard to new methods of treating the ore, such as pyritic smelting in place of roasting the ore before smelting. Many improvements were made in the town of Copper Cliff, and the removal of most of the roast beds from the vicinity of the town to a swamp behind the hills to the north permitted to some extent the growth of vegetation, so that the town was once more in sight of grass and green trees.

It was decided to build a new smelter on much improved and extended plans half a mile to the east of the west smelter, and the work was brought to completion in the fall of 1904. Meantime both the Ontario Smelting works and the west smelter were burned, hampering operations for the time. After this the low-grade matte was shipped to Victoria mines, whose smelter had been leased for six months from the Mond company, and there bessemerized, pending the completion of the converter plant of the new smelter. The two 550-ton furnaces of the new smelter are far larger than those of the old ones, and it is expected that they will permit an approach to pyritic smelting, so that a smaller proportion of the ore will require roasting than formerly.

The new works are very advantageously placed on a hill side, so that all ore and supplies may come in by rail at a high level, while tracks at the level of the valley below take charge of matte and slag, giving plenty of opportunity for disposing of the latter without clogging up the immediate surroundings of the smelter.

The company is now developing a large water power on Spanish river with which to supply electric power for all purposes at the smelter, thus saving fuel for steam, which is very expensive in the Sudbury region.

After a long period of conservative but prosperous work in the past, the company under new and progressive management, is making fresh departures in various directions; and it is to be hoped that the new methods will prove even more successful than the old.

H. H. Vivian and Company

Although the Murray mine was discovered before the Copper Cliff and Stobie mines, it was not worked until it passed into the hands of the famous Welsh metallurgical company, the Vivians, who began to develop it in 1889. With one or two short interruptions it was worked until 1894. In 1890 the first blast furnace was blown in, and the ore was treated in the usual way, by roasting in heaps, smelting in water-jacketed furnaces to a low-grade matte, and bessemerizing this to a high-grade matte. The Manhé converter was first used in the concentration of nickel matte at the Murray smelter. The low-grade matte is said to have contained only 9.4 per cent of nickel and 4.7 per cent of copper, giving cleaner slags than by the Copper Cliff method, which produced matte containing about 30 or 35 per cent. of the two metals. The bessemer matte at the Murray reached nearly the same grade as that of the Copper Cliff, running from 70 to 75 per cent. of the two metals. The high-grade matte was shipped to Swansea for final treatment.

Since 1894 the mine has remained closed down, but 5,000 or 6,000 tons of roasted ore were smelted in 1896, the matte being sent to the Whartons of New Jersey.

The ore is said to have contained 35 per cent. of iron, 23 per cent. of sulphur, 2 per cent. of nickel, 0.8 per cent. of copper, and about 40 per cent. of matrix. The pure sulphides averaged 3.6 to 3.75 of nickel and nearly half as much copper.

[54] Mineral Industry, 1903, p. 276.

Since then the only work done has been exploratory by diamond drilling at the Murray mine and also at the Lady Violet mine, on the north half of lot 1, con. IV, of Snider, about a mile and a half southwest of the Murray mine.

The Ontario Government drill was used toward the end of 1898 and the first half of 1899, but no definite statement has been made as to the results.[54]

Though the Murray mine was not one of the richest, it is probable that competent local management would have given better results than were obtained by management from England; and the failure and withdrawal from the region of so well known a firm does not necessarily condemn the mining district.

Dominion Mining Company

The Dominion Mining Company owned and worked for some time the Blezard mine, a mile north of the Stobie, in lot 4, con. II, Blezard township, and the Worthington mine at the station of the same name on the Sault branch about 25 miles west of Sudbury. The former mine was opened up in 1889, and in the following year the Inspector of Mines states that 50,000 tons of ore had been raised. A smelter was constructed and the ore, after being roasted in heaps, was smelted in Herreshoff furnaces to a matte averaging 27 per cent. nickel and 12½ per cent. copper, which was marketed without bessemerizing. The ore from the Worthington mine which was opened shortly after was partly rich enough in nickel to be shipped direct to market, while the rest was smelted with the Blezard ores. In 1893 the mines were shut down.

Mr. Robert McBride, who was in charge of the Blezard mine in 1892, says that for about a year and a half under his management the mine produced 3,000 tons of ore per month, but he was unable to estimate the amount raised before that. However, it seems probable that more than 100,000 tons had been raised before the mine was closed. The ore is said to have contained 5 to 7 per cent. of nickel and copper, the nickel being more than double the copper in amount, and apparently rivalling that of the Creighton in richness. Very little ore is left on the rock dump, showing that the work was done with unusual care.

The smelter treated not only the ore from the Blezard, but also that from Worthington, which began work in 1890, and continued to produce ore till September, 1894. Since then the mine has been shut down. The Worthington has produced the richest nickel ore in the district, running from 8 per cent. upwards; and specimens of nickelite occurring there reach 43 or 44 per cent. of nickel. The total amount of ore mined is, however, small, being estimated at only 25,000 tons.

Mond Nickel Company

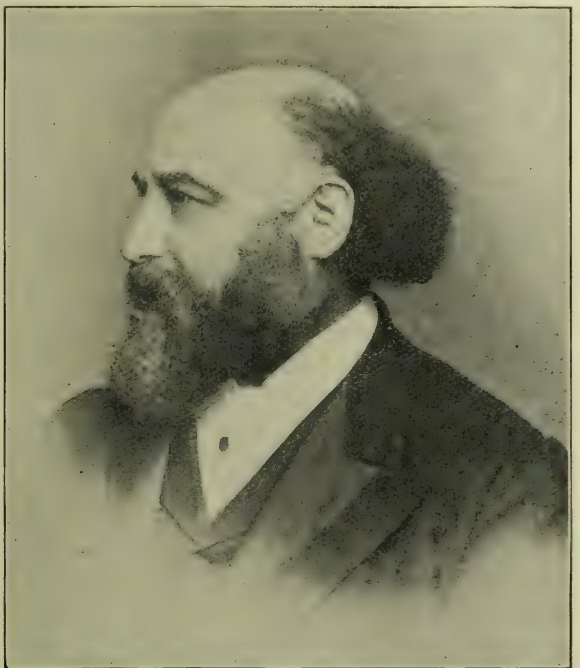
Dr. Ludwig Mond is known as the inventor of the carbon-monoxide method of refining nickel by volatilizing it in connection with this gas, and then depositing it again by suitable changes of temperature. Having found a method of refining the metal, he became interested in obtaining a deposit of the ore, and in 1899 bought the McConnell mine on the north half of lot 8, con. IV, of Denison township, about three miles northeast of Worthington.

The smelting works were located two miles south at what is now Victoria Mines station, on the Sault branch. The ore is transported 11,000 feet by an aerial tramway from the mine to the smelter, and mine and smelter are under the management of Mr. H. W. Hixon. At first the ore was roasted near the village on the railway, but later the roast beds were removed to a point about half way to the mine, and the vegetation, partly destroyed near the village, is reviving again.

Until the completion of the new Copper Cliff smelter, the plant at Victoria Mines was the most modern and complete in the district.

[54] Bur. Mines, 1901, p. 56.

The roasted ore is smelted in much the usual way to a low-grade matte, which is run into bessemer converters and blown until a matte of about 80 per cent. of nickel and copper is produced. This is shipped to the Mond nickel refinery at Clydach, Wales. It is said that difficulties arose in the refining process at first, so that the works at Clydach, were unable to refine the matte as fast as it was produced at Victoria mines. The mine and smelter were shut down, probably on this account, in December 1902, and were not in operation, except for a few months in the summer of 1903, until the latter end of 1904. It is believed that the difficulties have been overcome, so that the work of the mine and the smelter may now go on continuously.



Dr. Ludwig Mond, London, Eng., President Mond Nickel Company and inventor of the carbon monoxide method of refining nickel.

In 1902 the Mond company took an option on the North Star, or McCharles mine, on lot 9, cons. II and III, of Snider township, and also on the Little Stobie, two miles west of Blezard mine; and the ore from these mines was shipped to Victoria mines for treatment. Mining operations have been continued on the North Star, which seems to have developed into a good mine, but work was not long continued on the Little Stobie.

Lake Superior Power Company

The Lake Superior Power Company opened up two mines on the main nickel range, the Gertrude about two miles west of the Creighton, and the Elsie just west of the Murray mine. Their work began in 1899 with the Gertrude mine, which at that time showed pyrrhotite with very little chalcopyrite; and it was intended to use this ore for the production of the sulphur dioxide required in making sulphite pulp at Sault Ste. Marie; the roasted ore being afterwards electrically smelted to ferro-nickel. A considerable amount of copper pyrites was encountered later, and most of the ore of the Gertrude and also of the Elsie had to be treated according to the methods usual in the district.

Roast beds were prepared at Gertrude, where the ore from Elsie mine was treated also; and the roasted ore was melted to matte in water-jacketed furnaces.

The Elsie mine produced more than 35,000 tons of ore and the Gertrude 16,000, but all work on the mines and smelter ceased at the time when the company collapsed early in the summer of 1904. The matte was stored at the smelter, and methods of refining it have yet to be devised. A long series of experiments in the refining of nickel, electrolytically and otherwise, was made at the company's works at Sault Ste. Marie, apparently without finding a satisfactory process.

Other Companies

In addition to the companies whose history has just been sketched a number of ventures in mining and treating nickel ore have been made in the Sudbury district; but none have proved succesful, and few of them were of much importance. The Drury Nickel Company, having purchased the Travers or Chicago mine, on lot 3, con. V, Drury township, did some mining in 1891, and roasted and smelted some thousands of tons of ore in that year and in 1896. The matte was carried by a one-rail overhead tramway to Worthington station, seven miles away, to be shipped to the United States; but in 1897 the work was finally closed down.

At several other mines shafts have been sunk and considerable development work done, but none of them have raised any large amount of ore; nor have any of them operated smelters. References to them will be found in Dr. Barlow's very complete history of the development of the region;[55] so that details need not be given here.

Two attempts at novel methods of smelting and refining the ores should perhaps be mentioned. The Great Lakes Copper Company made an experiment of this kind at the Mount Nickel mine, on lots 5 and 6, con. II, of Blezard, between the Little Stobie and Blezard mines. The mine is stated to be well supplied with ore but the smelting works, planned by Anton Graf, of Vienna, were a failure, and work soon ceased. The Hoepfner Refining Company of Hamilton, undertook the electrolytic refining of nickel and copper in 1899, and constructed works just west of Worthington; but the process was unsuccessful, and a later attempt by Mr. Hans A. Frasch was likewise a failure; so that operations ended in 1901.

Some mention should be made of Mr. Edison's persistent endeavors to locate nickel properties in the region by dip needle methods. Mr. Edison's invention of what is stated to be an exceedingly light and efficient storage battery in which nickel plays a large part gave the incentive for the exploration. Three season's work covered most of the likely spots, where swamps or drift covered the ranges, and therefore where ordinary prospecting methods must fail of success; but the results have been negative. Several test pits and diamond drill holes have been sunk at points where there were notable disturbances of the dip needle, but no ore of importance was discovered. Similar work, but with more delicate instruments, has been carried on by the Mond and Lake Superior Power companies, in the first case by the well-trained Swedish engineer, Mr. Erik Nystrom; but the results leave doubts as to the value of this method of prospecting for pyrrhotite, though it is of great value in exploring for magnetic iron ore. The methods are described in detail and in a thoroughly scientific way by Dr. Eugene Haanel in a report on the "Location and Examination of Magnetic Ore Deposits by Magnetometric Measurements," issued by the Department of the Interior, Ottawa.

At the present time only two companies are actually at work, the Canadian Copper Company and the Mond Company. Both seem to be firmly established with good mines and satisfactory methods of smelting and refining the ore, so that the future should be prosperous. Most of the companies which have failed did so because of lack of capital

[55] G.S.C. Vol. XIV, Part H, pp. 34-38.

or of experience, or because they had no well worked out method of refining the matte. The smelting of roasted ore to make standard matte and the treatment of this matte in bessemer converters, so as to raise its contents of nickel and copper to 70 or 80 per cent., is comparatively simple; the real difficulty comes in the refining of the bessemer matte, and up to the present only two processes seem to be successful on the large scale, and both are in the hands of companies which have their own supplies of ore. There appears to be no market open for even the high grade matte, though the metal is in demand.

Of the two companies at work in the Sudbury district the Canadian Copper Company has much the largest holdings of nickel properties, including the greatest nickel mine in the world, the Creighton mine. There are still numbers of nickel deposits in the region in other hands, some of them large and promising; but the possession of the Creighton mine gives the Canadian Copper Company a distinct advantage over its possible rivals, since at present there is no prospect that any other deposit will equal that famous mine.

It is natural that the Canadian Copper Company should have aroused some hostility and jealousy in its long and successful career; but it is only fair to add that its steady persistence in developing the nickel resources of the region has been the mainstay of mining in the Province of Ontario for a number of years, and a fair reward should be reaped for its constancy in going on with its work under discouraging conditions in its earlier years.

Other Nickel Regions

Nickel is a widely spread metal, but very few regions contain its ores in quantities that can be profitably mined. Outside of the deposits connected with the great eruptive sheet which has been described in earlier pages, pyrrhotite with some nickel has been reported from many other points in northern Ontario, especially at the east and south west of the main nickel region. Numerous small deposits of pyrrhotite occur near Nairn Centre, southwest of Worthington, and a small amount of work in the way of stripping has been done upon some of them, without important results; though ore containing 1.95 of nickel is reported from lots 1 and 2, con. III, of Nairn. The deposits here and in Lorne may really be connected with the Worthington offset, though the ore found in them is much lower in nickel.

To the east of the nickel eruptive, northeast of lake Wahnapitae, several locations were taken up years ago for nickel. Ore from Boucher's mine gave 1.57 per cent. of nickel, or 2.1 per cent., if pyrrhotite free from gangue be taken. Similar small bodies of pyrrhotite occur south of Ramsay lake. All these deposits have a possible connection with the main nickel eruptive, but all are small in size and low in grade.

Much larger masses of pyrrhotite have been found in other parts of northern Ontario, as between lake Temagami and Net lake, but of too low a grade to be of importance.[56]

Much more promising are the extraordinary deposits of native silver, cobalt and nickel ores of Coleman township near lake Temiskaming, where considerable quantities of one of the richest ores of nickel occur. Mixed with smaltite one finds large masses of nickelite; so that nickel is one of the valuable ingredients of the ore, though cobalt and silver are of much more importance. Unless much larger deposits of this ore are found, the Temiskaming mines will not prove serious competitors of the Sudbury region as nickel producers. Detailed accounts of these remarkable deposits are given by Prof. W. G. Miller in this and former reports of the Bureau of Mines.[57]

Nickel ores have been reported from many other parts of Canada, especially British Columbia and New Brunswick. Near St. Stephen in the latter province pyrrho-

[57] Bur. Mines, 1904, pp. 96-101. [56] Bur. Mines, 1900, pp. 173-4.

tite with a little copper pyrites is found in masses of gabbro cutting slate, the amount being considerable; but the ore contains only from .92 to 2.62 nickel, with some cobalt and copper, so that the ore is low as compared with Sudbury ores.[58]

Dr. Barlow mentions numerous other localities in Canada where trifling amounts of nickel ore have been found, usually much lower in nickel than the Sudbury ore, and none of them likely to be of practical importance.[59] With his very complete account there are tables showing the results of a large number of assays of such ores, made in Dr. Hoffman's laboratory at Ottawa.

UNITED STATES NICKEL DEPOSITS

The first nickel produced in America was obtained in 1863 from the Gap mine in Lancaster county, Pennsylvania; and it has a special interest to Canadians, since the methods adopted by Joseph Wharton in refining the metal were later of importance in the treatment of our own ores. The mine contained mainly pyrrhotite and chalcopyrite, and, like the Sudbury deposits, was first taken up for its copper ore, the nickel contents of the ore being discovered later. It is associated with an eruptive mass of a much more basic kind than the Sudbury norite, and like the Sudbury ore deposits, was probably due to magmatic segregation. The ore was of much lower grade than the Canadian, yet for a number of years it was the most important nickel mine in America. After running from 1863 to 1891 it was finally closed down in the latter year.[60]

Nickel ores of an entirely different type, resembling those of New Caledonia, have been found in Oregon and North Carolina. The Oregon deposits, in Douglas county, are irregular masses of hydrated silicates of nickel and magnesia in serpentine, formed by the alteration of peridotites or related rocks. The ore occurs as loose boulders on the surface and in veinlets in the serpentine, but, up to the present, no ore bodies of workable dimensions have been found. In North Carolina, the relationships are similar, and the pale green mineral genthite, a hydrous silicate of nickel and magnesia was discovered there. No ore of importance has been mined, however.

A small quantity of nickel occurs with the lead ores of Mine la Motte in Missouri; and the metal is recovered as a by-product in the treatment of the ores. In 1903 the United States is reported to have produced from domestic ores 57 tons of nickel, apparently from this mine.

Though the United States has dropped out of the race as a producer of nickel ore, it is still one of the most important countries for the refining and utilization of the metal nickel; much the greater part of the Canadian matte being treated at Constable Hook, New Jersey.

EUROPEAN NICKEL DEPOSITS

The metal nickel was first produced in any quantity at Schneeberg in Saxony; and ever since the discovery of the metal a small amount of nickel and cobalt has been obtained at the Freiberg smelters as a by-product in the treatment of silver-lead ores. A little has been produced also from the deposits of Varallo, in Piedmont, Italy, where the ore is pyrrhotite, which occurs with basic eruptive rocks, as in so many other places. In Austrian Silesia nickel is extracted from a silicate forming veins in serpentine, resembling the New Caledonian deposits; but the amount is small.[61]

At Schaud on the Spree in Germany comparatively rich ore, with 5.52 to 6 per cent. of nickel and a little cobalt and copper, is found beside a dike of diabase-gabbro

[58] G.S.C., Sum. Rep. 1903, pp. 156-9; also 1904, Part H. p. 151-3.
[59] Ibid., Part H, pp. 147-166.
[60] Kemp, Ore Dep., U.S., and Can., p. 432; 2nd Geol. Sur. Penn., Rep. CCC, 1880; G.S.C. 1904, Part H, pp. 174-6.
[61] References to many of the localities are given by Dr. Barlow in the report previously mentioned.

(proterobase); but Beck, who describes it, thinks the deposit was not formed by segregation but by ascending waters. He objects also to Vogt's theory regarding Sudbury and Norwegian ores. However, conclusions drawn from the small deposits he refers to should hardy overturn those formed from more numerous and larger deposits elsewhere.[62]

Scandinavia has hitherto proved much the most important nickel mining region in Europe, and before the importation of New Caledonia ores most of the world's nickel came from the mines of Norway and Sweden. Since 1894 these countries have fallen off greatly in their output of the metal, however, and during some years nickel mining ceased altogether. The Scandinavian deposits are of pyrrhotite, like our own, and are associated with gabbro or norite, but of a more basic type than the Sudbury norite. They have a special interest to students of the Canadian region, since the true theory of the relationship of ore to rock was worked out first in Norway, by Professor Vogt of Christiania, and afterwards applied to our deposits by Dr. Adams, Dr. Barlow, and others.[63]

In Norway there are about 40 deposits, and quite a large literature has sprung up about them, partly written by Canadian observers,[64] but it will be impossible to do more than give a general account of the ore deposits as compared with those of Sudbury. Nothing resembling the great eruptive sheet of the Sudbury region has been described in Norway, though the ore always appears as segregations at the edge of masses of gabbro. Between the ore and the rock there is pyrrhotite-gabbro, showing every stage of mixture of the sulphides with the rock. The sulphides are mainly pyrrhotite, but include also chalcopyrite, though in less amount than in some of our offset mines. Pyrite is more frequent than with us, but the rarer elements, gold, silver, and platinum seem to be present in less amounts, though they always occur. In richness the ore is much like our own, running from 2.5 to 5 per cent. of nickel. At Evje, for instance, the ore contains from 2.90 to 4.37 per cent. of nickel and 1 to 1.30 per cent. of copper. The deposits, however, are much smaller than the Canadian ones, so that their competition is not to be feared.

In Sweden very similar deposits exist, but the number exploited is smaller. At Kuso pyrrhotite has segregated from gabbro-diorite, and, as worked, runs 1.14 to 1.82 of nickel, the pure pyrrhotite containing 2.51 to 3.42 per cent.[65]

In 1893 and 1894 Scandinavia produced more than 100 tons of nickel, but the opening up of the New Caledonia and later the Sudbury mines have almost destroyed the nickel mining industry in those regions.

NEW CALEDONIA

The only real competitor of Ontario as a nickel producer is the French penal colony, New Caledonia, in the south seas. Nickel was discovered there in 1865 by M. Jules Garnier, and it was through his exertions that the nickel mining industry sprang up. Many accounts of the region have been given, the most complete description of the mines and their conditions being by M. E. Glasser, who examined them for the French government;[66] but a good sketch of the subject is given by Dr. Barlow in the report so often referred to. The following account is drawn from M. Glasser.

The island consists of ancient schists and mesozoic sediments, penetrated by numerous eruptives, of which the most important is a very basic rock, peridotite, consisting of

[62] Die Nickelerzlagerstätte von Schaud au der. Spree u. ihre Gesteino, zeitschv. deutsch. Geol. Ges., 55, 1903, pp. 296-330.

[63] Nikkel forekomster og Nikkelproduktion, Geol. Soc. Nor. Christiania, 1892; Ueber die Bildung von Erzlagerstätten durch Differationprocesse in Eruptivmagmaten, International Geol. Congr., Zurich, 1894; Problems in the Geology of Ore-Deposits, in Genesis of Ore Deposits, Posepny, 1901, p. 636, etc.; Formation of Eruptive Ore Deposits, Min. Industry, 1895, p. 743, etc.; and various other papers.

[64] Macfarlane, Can. Nat., Vol. VII, p. 13, Nickel ore at Ringerike; Major Leckie, Nickel Deposits in Norway, Can. Min. Rev., Vol. XVIII, No. 8, p. 151-3.

[65] Löfstrand, Slattberg's och Kuso Nickelgrufnor, Geol. För. in Stockholm Förh. 25, 1903, pp. 103-122.

[66] Au. des Minis, 10 Séries, Tome IV, 1903, pp. 299-392, and 397-536.

olivine and enstatite, now more or less transformed into serpentine. Deposits of nickel, cobalt and chromium are associated with the serpentine. The original peridotite is no doubt the source of the ore, and analyses show that the fresh rock contains small percentages of nickel and cobalt. A specimen of olivine from one of the mines contains 0.11 per cent. of nickel and cobalt oxide, while the enstatite associated with it in less amount contains 0.4 per cent. Examples of peridotite are said to have been found containing as much as 2½ per cent. nickel. The peridotites cover most of the southeast end of the island and form a discontinuous chain of outcrops running nearly to the northwest end, as a mountain range rising in places to 5,500 feet. In most cases serpentization has advanced far, and at many points the serpentine has changed into a red clayey material, which is associated with nickel ore.

The ores are all hydrated silicates in which nickel has replaced magnesia to a greater or less extent. The richest silicates, which are green and soft, may contain even 48.6 per cent. of nickel oxide, and are called garnierite and noumeaite, the two varieties seeming to blend into one another. Their composition varies greatly, but their nickel contents averages higher than that of the genthite referred to as occurring in Oregon and North Carolina.

The green minerals occur as small veins in the serpentine or peridotite, as a scaly covering of fragments of the rock, or as concretionary masses. The color varies from pale to deep green or almost black, and the garnierite is associated with a chocolate brown mineral, which was at first rejected, but is now known to be a similar nickel ore colored with iron oxide, and forms the larger part of the ore mined. There are also silicious masses of a green color, containing, however, only 9 or 10 per cent. of nickel.

As examples of the best garnierite the following analyses may be given from M. Glasser's report:

——	I.	II.	III.	IV.	V.	VI.	VII.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	42.61	35.45	44.40	37.78	38.35	37.49	47.90
NiO	21.91	45.15	38.61	33.91	32.52	29.72	24.00
MgO	18.27	2.47	3.45	10.66	10.61	14.97	12.51
$Al_2O_3 + FerO_3$	.89	.50	1.68	1.57	.55	.11	3.00
FeO	....	....	.43	....	....	....	....
CaO	....	....	1.07	....	....	....	trace
H_2O	15.40	15.55	10.34	15.83	17.97	17.60	12.73
	99.08	99.12	99.98	99.75	100.00	99.89	100.14

There may be every gradation from specimens like these, which come from different parts of the island, to silicate of magnesia with only a small percentage of nickel, so that the ore has the composition of serpentine in which a variable amount of nickel has replaced magnesia.

M. Glasser distinguishes four varieties of ore deposits, vein-like deposits, brecciated deposits, masses of altered serpentine impregnated with nickel, and nickeliferous earths.

While the pure garnierite is very rich, most of the ore is of very much lower grade, and the miners mix rich and poor ore so as to adjust the output to an average of 7 per cent. of nickel, after drying at 100° C. This means practically that the hydrous ore, before drying, runs about 5¼ to 5½ per cent. of nickel, since the percentage of water is high. The waste dumps may contain 3 or 4 per cent. of nickel.

The veins are seldom large, and are never worked to any important depth, so that there are few underground mines. Most of the deposits form sheets covering the surface, nowhere more than 15 or 20 feet thick, and are worked as open pits. The largest group of mines mentioned by M. Glasser, on the plateau of Thio, had produced

up to the time of his report 250,000 tons; and during its greatest prosperity, in 1890-1894, had reached a production of 25,000 or 30,000 tons per annum, which later had fallen off to 10,000 tons. The tenor of the ore in early days was 10 to 12 per cent. but latterly had fallen to 6½ per per cent. of nickel. A large amount of waste rock has now to be rejected, and the group of mines is approaching exhaustion.

The deposits are always found on gentle slopes or basins on the flanks of the mountains and lie between the red clay mentioned before and the rock. They have resulted from the superficial weathering of the rock, accompanied by a concentration of the nickel as silicate by surface waters, the nickel being precipitated more readily than the magnesia. Under these conditions none of the deposits can be expected to cover continuously a large surface. The largest of the bands of ore are not more than about a half mile long, and they are comparatively narrow. Many of the deposits are already worked out, but a large number still furnish ore, and probably many new deposits will yet be found. If the grade of the ore required were lowered to 5 per cent. of nickel, the amount which could be furnished would greatly increase.

As the ores generally occur high up on the mountains where roads are difficult to construct, transportation is a serious difficulty, and cable tramways have often to be provided. Another drawback is the thickness of red clay which has to be stripped from many of the deposits before they can be worked by open quarrying, which is the usual method. The poor character of the labor available, Kanakas, convicts, or sometimes Japanese, is another drawback mentioned by M. Glasser; who adds that the long ocean voyage and the remote situation of the island greatly hamper the marketing of the ore at a profitable rate.

At present all the ore is shipped to Europe for treatment, but it is thought that a great economy in freight could be accomplished by smelting to matte in the island, thus reducing the weight, though smelters erected years ago proved unsuccessful.

Though nickel was discovered by Garnier in 1865, scarcely any mining was done until 1875, and the output did not rise to great importance till 1889, when 21,000 tons of ore were shipped. This amount had increased to 103,908 tons in 1899, and to 128,653 tons in 1902, acocrding to statistics furnished by M. Glasser. In 1889 the contents of nickel in the ore sent from New Caledonia rose to 1,680 tons, while previously it had not reached 1,000. In 1902 the nickel contents were placed at 7,045 tons, though M. Glasser doubts the correctness of the return.

The most productive mines are still the old ones in the neighborhood of Thio on the northeast side of the island near its southeast end, but their output is diminishing and the total is kept up by the working of a large number of small veins in different parts of the island.

M. Glasser discusses interestingly the formidable competition of the Canadian nickel mines, though he states that "thanks to a more or less complete understanding between the producers, New Caledonia preserves her rank; but it is none the less true that the nickel industry is developing in Canada and that the production of its mines has been rapidly increasing of late years. Must one say that New Caledonia has much to fear from this competition? We do not think so; for, so far as we can judge from the documents at our disposal, the natural conditions of the Canadian deposits are, in themselves, much less favorable than those of our colony." He goes on to show that the Sudbury ores are sulphide ores of nickel and copper, variable in the percentage of the two metals and requiring a complex method of refinement. Quoting the statistics of the Bureau of Mines, he admits that the nickel resources of the region are considerable, though the tenor of the ore seems to be diminishing.[67] He was influenced in his view by the absurdly high estimate of our ore reserves given by an official report to the United States Secretary of Marine in 1890.

[67] The statistics quoted reach only to 1901, before the rich Creighton ores had produced an effect.

While M. Glasser thinks our prospects less bright than those of New Caledonia, he admits certain advantages. "On the other hand the general industrial situation of Canada appears to be very favorable, and has permitted in late years an important development in mining and treating the ores, in consequence of which the production of nickel in Canada is steadily increasing."

There is one apparent advantage for purposes of treatment, which the New Caledonian ore has over ours, in the absence of sulphur, and another real advantage, in its freedom from copper. The first advantage is, however, neutralized by the fact that the New Caledonian ore must be smelted with coke, which always contains appreciable quantities of sulphur. Owing to the great affinity of nickel for sulphur, this is taken up by the metal, and must later be separated from it. This fact interfered with Garnier's original idea of direct smelting of the nickel; and it is now smelted with sulphur compounds, such as gypsum, and made into a matte which must afterwards be refined in ways not very different from our own. The absence of copper makes its separation unnecessary, but the copper, when separated, is an element in the value of the Sudbury ores.

TYPES OF NICKEL ORES AND DEPOSITS

From the account just given of the New Caledonian ore deposits it will be seen that they are of an absolutely different type from those of Sudbury; and, if we omit the few rich arsenides and sulphides of nickel found in some Saxon mines and the Coleman deposits, in relatively minute quantities, all nickel deposits may be divided into two classes, pyrrhotite ores which occur as segregations at the margin of eruptive rocks such as norite and gabbro; and hydrous silicates, such as garnierite and genthite, which result from the weathering of serpentine derived from a very basic eruptive rock, peridotite.

Though both kinds of deposits have their source in eruptive rocks, one comes directly from the molten magma, by segregation at its bottom or edge; the other by a complex process of decomposition carried on in two stages, hydration into serpentine, and weathering of serpentine into red clay, with the accumulation of the minute quantity of nickel in the original rock as secondary deposits of the green or chocolate brown hydrous silicates of nickel and magnesia. In the Sudbury region the silicate ore of nickel is unknown, though genthite has been found on Michipicoten island in lake Superior[68] in trifling quantities. We have numerous areas of serpentine in Canada, especially in the Eastern townships of Quebec, and minute amounts of nickel occur in them, but the conditions have not been favorable for the accumulation of secondary ore deposits, even if the amount of nickel contained in the serpentine was sufficient in quantity. The scouring of the Ice Age would have removed any such residual deposits.

The Scandinavian nickel regions have, of course, passed through the same conditions as our own. It is a little surprising that the millions of tons of nickeliferous pyrrhotite destroyed in past ages by weathering in the Sudbury region should not somewhere have given rise to secondary deposits, but none are known; and we must suppose that the nickel solutions due to weathering and gossan formation have not met with the proper re-agents to precipitate the nickel. Its compounds are in general very soluble, only the hydrous silicate showing a tendency to permanence.

On the other hand sulphide of nickel is practically never found in New Caledonia, the only reported occurrence being a little millerite found in the Esperance chromium mine.

We have then in Ontario very large deposits of sulphide ores going to depths of more than 1,000 feet, comparatively little changed from the form they assumed on cooling from the molten magma; while in New Caledonia we find thin, flat, shallow

68 G.S.C., 1890-91, Part E, p. 47; also Dr. Barlow, 1904, Part H, p. 149.

sheets of ore entirely of secondary origin, the accumulation of ages of superficial changes in a region too near the equator to be affected by the glacial period.

For completeness sake a reference should be made to the occurrence of native nickel, associated with native iron, in certain basic rocks, as at Ovifak on Disco island, on the Greenland coast. The masses of iron found there and partly removed by Nordenskjold to be deposited in the Scandinavian capitals, run up to 20 tons in weight. They contain only small amounts of nickel, from 0.34 to 2.85 per cent., but almost enough for nickel steel. Meteoric iron, it is well known, always contains nickel, reaching even in one case, 59.69 per cent., as at Octibbeha Co., Miss.

Native nickel with a percentage of iron has been found, also, the example best known being the awaruite of Gorge river in the south island of New Zealand. This contains 67.63 per cent. of nickel, 0.70 per cent. of cobalt, and 31.02 per cent. of iron. It is found with gold and platinum, etc., in river gravel, and was probably derived from a partially serpentinized peridotite.[69] Even more interesting is the souesite, or native iron-nickel alloy described by Dr. Hoffman from Lillooet in British Columbia. It was found with platinum and a little gold, etc.; and has the composition nickel 76.48, iron 22.30, copper 1.22.[70] Closely related to this are the metallic grains found by Sella in gold-bearing sand at Elvo, near Biella, in Piedmont; which contain 75.2 per cent. of nickel and 26.6 per cent. of iron.[71]

Distribution of Metals in the Sudbury Ores

By far the most important of the metals in the Sudbury district, so far as quantity is concerned, is iron; but it is always combined with sulphur, chiefly in the form of pyrrhotite, which contains from 60.4 to 61.6 of iron when pure. If it were not for the difficulty in completely removing the sulphur, pyrrhotite would be a valuable ore of iron, and the nickel mines would also be iron mines, some of them comparable in tonnage and percentage of the metal to important iron mines in other regions. Some day the iron of the pyrrhotite may be in demand, but that day is probably distant.

Next in amount comes nickel, which may be looked on as sometimes replacing a part of the iron in the pyrrhotite, though in most cases it is known to belong to pentlandite disseminated through the pyrrhotite. This occurs in quite variable amounts, running, in mines which have been extensively worked, from 1.5 per cent. of the ore to over 5 per cent.; and in some smaller mines to 8 or more per cent. for a few thousand tons. These statements apply, however, to the ore as mined, always including more or less rock. The pure sulphides would, of course, run higher. In the Murray mine 55 to 60 per cent. of the ore was sulphides; at the Copper Cliff nearly 40; at No. 2 about 60; at the Frood 73; and at Creighton 79 or 80, the highest in the region.

Close after nickel comes copper, derived from the chalcopyrite almost always mixed with the pyrrhotite; but the proportions of the two metals vary greatly.

Next in quantity, but far behind the others, is cobalt, present in all the ores to the extent of from 1-40 to 1-133 of the nickel present, according to the few analyses on record showing the percentage of cobalt in high-grade matte. If we take the returns of cobalt from the statistics for 1903-4, we find only 25.8 tons to 11,727 tons of nickel, the cobalt representing only 1-455 of the nickel; however, cobalt is more easily slagged off than nickel, and no doubt has been quite disproportionately removed in the refining process. For the same reason the proportion of cobalt in the bessemer or high-grade matte is no doubt lower than in the original ore.

The precious metals are present in still smaller quantities, silver coming first, with 2½ to 7 oz. per ton of high-grade matte; the platinum metals next, with from 0.17 oz. to 0.5 oz., and gold last, with 0.02 to 0.3 oz. per ton.

69 Dana's System of Mineralogy, pp. 28 and 29.
70 Am. Jour. Sc., Vol. XIX, 1905, pp. 319-20.
71 Dammer, Handbuch der Anorganischen Chemie, Vol. III, p. 488.

Matte Analyses

The results of the most complete analyses of bessemer or other high-grade matte available are given in the following table:

——	I.	II.	III.	IV.	V.	VI.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Nickel	48.82	41.58	40.37	41.18	39.96	41.88
Cobalt		0.71	0.78			40.33
Copper	25.92	24.99	24.95	44.87	43.36	37.37
Iron	2.94	9.82	9.64	0.94	0.30	1.07
Sulphur	22.50	....	....	11.63	13.76	....
Gold	0.02oz.	0.15oz.	0.10oz.	0.30oz.	0.1 to 0.2 oz.	0.66oz.
Silver	3.14 "	....	2.50 "	5.10 "	7.0 "	4.87 "
Platinum	0.13 "	0.50oz.	0.44 "	....	0.5 "	.40 "
Iridium	0.02 "	....	....	....	....	....
Osmium	0.02 "	....	....	....	....	....
Rhodium	trace	....	....	....	....	....
Palladium	trace	....	....	....	....	....

I is by T. L. Walker of Murray mine bessemer matte.[72]

II and III are by Donald Locke, of Ontario Smelting Works matte,[73] mainly from Creighton ore.

IV is by J. W. Bain, of Copper Cliff matte in 1899, from Stobie, Copper Cliff and Evans mine ore.[74]

V is by Titus Ulke in 1894, of Copper Cliff and Evans ore, probably with some ore from Stobie.[75]

VI is by Donald Locke, of Victoria mines bessemer matte.[76]

Analyses I, II and III are of matte whose ore came chiefly from large marginal deposits, the Murray and Creighton mines. IV and V are partly of ore from mines of the Copper Cliff offset (Copper Cliff and Evans), but partly from Stobie mine. VI is from an offset mine, but very close to the margin of the nickel-bearing eruptive, Victoria mine. It will be noticed that nickel predominates over copper in the ratio of about 2 to 1 or 5 to 3 in matte from marginal mines, while copper outweighs nickel in offset mines, except at Victoria mine, where nickel is a little in advance.

Assays of ore from the different mines show this even more strikingly. The Creighton runs about 5 per cent. of nickel to 2 of copper; the sulphides at the Murray mine about 3½ to 1½; the Blezard mine about 4 of nickel to 2 of copper; and similar proportions are found in the Gertrude, etc., all marginal mines. At the Copper Cliff the ore averages 4.20 of nickel to 5.68 of copper, and the offset mines as a whole contain nearly equal amounts of nickel and copper, except the Stobie offset, where nickel is 2.21 to 1.55 of copper. The last offset is of a peculiar kind, showing no direct connection with the main eruptive, but running parallel to its edge at a distance of about three-fourths of a mile to the southeast, so that it seems to follow a different law, and may be really a sheet of norite and ore projecting from the main range away below the surface.

It appears then that a certain amount of segregation of the ores took place where offsets projected from the edge of the eruptive into the cooler country rocks, the process being aided probably by circulating hot water arising from the eruptive magma.

Assays or analyses are not available to show how the rarer metals were affected, beyond the general fact that they seem to have been concentrated in a still higher degree than the copper, as may be seen from the table. The first three analyses show

72 Am. Jour. Sc., Vol. 1, 4th Series, 1896, p. 112.
73 Dr. Barlow, p. 206.
74 Bur. Mines, 1900, p. 218.
75 Min. Industry, Vol. III, p. 460.
76 Dr. Barlow, p. 206.

2½ or 3 ounces of silver per ton of matte and from 0.19 to 0.65 of gold and the platinum metals; the last three have from 5 to 7 ounces of silver and from 0.6 to 1 ounce of gold and platinum. The amount of the precious metals is more than doubled, while the percentage of copper is increased from 25 to about 42.

In the case of Vermilion mine the gold and platinum metals are increased in a much greater degree, but the small amount of the ore known to exist makes it of little importance. No analyses of Worthington matte are available, unfortunately.

The Precious Metals

The proportions of the rare metals thus far referred to are the results of analysis of the high-grade matte. To bring them into relationship with the respective ores from which the matte was obtained it is necessary to know the grade of the ore, and in many cases this is not on record. At the Murray mine the ore contained in 1891 about 1.5 per cent. of nickel and 0.75 per cent. of copper; so that a ton of matte containing 74.74 per cent. of the two metals represented the concentration of about 33 tons of ore. If 20 per cent. be allowed for loss in treatment, this would raise the amount to 40 tons. Of this about 60 per cent. was sulphides, making 24 tons of pyrrhotite and chalcopyrite to furnish 3.14 oz. of silver, 0.17 oz. of platinum metals and 0.02 oz. of gold. Probably 12 tons of the Creighton sulphides produced a ton of the matte analysed by Mr. Locke (II and III); while about 18 tons of the sulphides from Stobie, Evans, etc., were needed for IV. In the case of V probably 12 tons of the rich sulphides from Copper Cliff and Evans provided a ton of matte. I have no definite information as to the number of tons of sulphides required to produce a ton of the Victoria mines matte (VI).

Aranged as a table the amounts of the rare metals to a ton of sulphides are roughly as follows:

	Silver.	Gold.	Platinum metals.
I. Murray mine	0.13 oz.	0.0009 oz.	0.007 oz.
II and III. Creighton mine, etc.	0.21 oz	0.0083 oz.	0.037 oz.
IV. Copper Cliff, Stobie, etc.	0.28 oz.	0.0166 oz.	
V. Copper Cliff, Evans, etc...	0.583 oz.	0.0125 oz.	0.0146 oz.

II and III included some ore from the offset mines of the Canadian Copper Company, and do not represent the Creighton alone.

In concluding this discussion of the distribution of the rare metals the returns of platinum and palladium from the Canadian Copper Company's matte must be referred to. In 1902 there were 2,375 ounces of platinum and 4,411 ounces of palladium recovered, which may be looked on, however, as belonging partly to the ore mined in former years. Assuming that it came from the ore of 1902 there were 0.0102 ounces of platinum and 0.0189 ounces of palladium to the ton of ore mined, or 0.0291 of both metals. Probably 60 or 70 per cent. of the ore was sulphides, so that the number of ounces per ton should be increased proportionately. In 1903 the amounts are 0.0077 platinum and 0.0144 palladium, the total being 0.0221 ounces. In 1904 there was a falling off to 0.0052 and 0.0093, with a total of 0.0145 ounces of the platinum metals per ton of ore. In the last year most of the ore was from the Creighton mine and 75 per cent. of it may have been sulphides, which would raise the total to 0.0193 ounces per ton.

Estimating roughly the amount of sulphides in the ore each year, the following relationship results:

1902—Platinum	metals	per ton	of sulphides,	0.0468	ounces
1903—	"	"	"	0.0323	"
1904—	"	"	"	0.0193	"

A portion of the ore from which the metals were obtained in 1904 probably came from the Copper Cliff in the previous year, so that we cannot assume Creighton ore that the statistics of the rare metals do not represent the complete change from offset to the statistics of the rare metals do not represent the complete change from offset to marginal ores in this respect.

One naturally compares our ores with the similar ones of Norway, but in comparing the ratios of the metals in the two countries it must be kept in mind that their deposits correspond to our marginal ones and not to our offset deposits. Prof. Vogt gives the composition of two Norwegian bessemer mattes as follows:

	Ringerike. Per cent.	Evje. Per cent.
Nickel	51.16	41.50
Cobalt	1.98	0.97
Copper	16.40	23.00
Iron	10.87	(13)
Sulphur	19.58	(20)
Gold	0.0145 oz. per ton	0.029 oz. per ton
Silver	2.46 " "	4.06 " "
Platinum	0.075 " "	0.09 " "
Iridium, Osmium } about	0.003	

If this is compared with the table of analyses of Sudbury mattes given on a previous page, it will be seen that the proportions are quite like analyses I, II and III, from marginal ore deposits, but that the other three show higher percentages of the rare metals. It will be noticed, too, that the percentage of copper in the three offset deposits is much greater than in the Norwegian mattes.

Palladium has not, so far as I am aware, been reported from the Norwegian nickel ores.

Prof. Vogt states that in Norway the proportions of the metals are one part of gold to 120 of silver, one of platinum to 30 of silver, one of silver to 5,000 of nickel.[77] In our ores it would be more natural to compare the precious metals with copper than nickel, since their percentage increases with that of copper, though somewhat more rapidly.

It is well known that platinum occurs always in connection with basic rocks, but the native metal in Russia, British Columbia, etc., is considered to be derived from rocks consisting of olivine and proxene, now largely turned to serpentine, rocks of a much more basic character than our norite; and it seems that the native metals of the platinum group go with ultra-basic rocks, while the arsenical compound, sperrylite, is associated with less basic rocks like norite and gabbro. New Caledonian peridotites, from which their nickel ore is derived, should contain a small amount of the platinum group of metals, but in the native state and not as arsenides, if the relationship just mentioned is correct.

Statistics of Nickel Production

SUDBURY DISTRICT

Year.	Ore		Nickel			Copper.			Cobalt.		
	Tons raised.	Tons smelted.	Tons Ni.	Ni. %	Value $	Tons Cu.	Cu. %	Value $	To's Co.	Co. %	Value.
Before 1890....	100,000										
1890....	130,278	59,329									
1891....	85,790	71,480									
1892....	72,349	61,924	2,082	3.36	590,902	1,936	3.19	234,135	8½	.0137	3,713
1893....	64,043	63,944	1,653	2.21	454,702	1,431	2.38	115,200	19	.0299	9,400
1894....	112,037	87,916	2,570½	2.92	612,724	2,748	3.14	195,750	3¼	.0037	1,500
1895....	75,439	86,546	2,315¾	2.67	404,861	2,365½	2.73	160,913			
1896....	109,097	73,505	1,948½	2.67	357,000	1,868	2.54	130,660			
1887....	93,155	96,094	1,999	2.08	359,651	2,750	2.86	200,067			
1898....	123,920	121,924	2,783¾	2.28	514,220	4,186¾	3.43	268,080			
1899....	203,118	171,230	2,872	1.67	526,104	2,834	1.68	176,236			
1900....	216,695	211,960	3,540	1.67	756,626	3,364	1.58	319,681			
1901....	326,945	270,380	4,441	1.64	1,859,970	4,197	1.55	589,080			
1902....	269,538	233,388	5,945	2.54	2,210,961	4,066	1.74	616,763	6.1	.0026	2,873
1903....	152,940	220,937	6,998	3.17	2,499,068	4,005	1.81	583,646	13.1	.0058	6,123
1904....	203,388	102,844	4,729	4.60	1,513,280	2,042	1.98	285,966	12.8	.0124	6,060
Totals.	2,338,732	1,933,401	43,877½	2.434	12,660;069	37,793½	2.09	3,876,177	62.⅔	....	29,969

77 Zeitschrift f. prakt. Geol., Heft 8, Jahrgang, 1902, pp. 258-60.

For the nine months ending 30th September 1905, the production of nickel from the Sudbury mines was returned as 7,136 tons. worth in the matte $2,522,593, and of copper 3,310 tons, worth $507,440.

In addition to the metals given in the table there are returns for platinum and palladium from 1902 to 1904, as follows:

——	Platinum.			Palladium.		
——	Oz.	Oz. % or ton	Value	Oz.	Oz. per term %.	Value.
1902	2,375	0.0102	46,323	4,411	0.0189	86,015
1903	1,710	0.0077	33,345	3,177	0.0142	61,951
1904	536	0.0052	10,453	952	0.0092	18,564
	4,621	....	90,110	8,540	....	166,530

The statistics as given are taken from the reports of the Bureau of Mines, and represent the returns sent in by the companies. For some reason not accounted for, the statistics given in the Geological Survey Reports differ considerably from those of the Bureau of Mines, being generally lower. The values in the two sets of statistics vary still more, since the Bureau of Mines reports spot values of the nickel and copper in the matte as it is shipped from Ontario, while the Survey reports the final value of the refined metal.[78]

Certain interesting changes in the tenor of the ore smelted may be observed in the table given above, such as the gradual falling off in the nickel and copper per ton, from 3.36 and 3.19 respectively in 1892 to 1.64 and 1.55 in 1901; followed by a rise in the next three years to 4.60 and 1.98. This may be accounted for by the fact that the ores came largely from differnt mines at different times. In the early days the rich Copper Cliff mine provided a large part of the ore; later lower-grade ores from the Stobie and other mines came in plentifully and lowered the average. For the last three years the comparatively rich Creighton ore has been replacing that from other mines, raising the percentage; but as this mine produces much more nickel than copper, about 5 per cent. to 2, the proportions of the two metals have changed. The Copper Cliff supplied about equal quantities of nickel and copper, usually rather more of the latter metal.

The absence of cobalt from the statistics from 1895 to 1900 does not imply that the ore contained none, but only that it was not reported, perhaps because not separated from the nickel. The amounts reported from 1892 to 1894 were from a company which ceased work in the latter year.

The most curious part of the table is that referring to platinum and palladium. Platinum has long been known to occur in the matte, but except in one assay of Copper Cliff matte, palladium has been reported only in traces.[79] It is therefore a surprise to find nearly double as much palladium as platinum, and the fact is not easily accounted for, since no palladium mineral has been found in the district. The platinum comes, of course, from sperrylite.

The falling off in the percentages of these rare metals from 1902 to 1904 may have been caused by the closing down of most of the offset mines, such as the Copper Cliff, confining the ore to marginal mines, such as the Creighton. Offset deposits, like the Copper Cliff, Victoria mine and Vermilion, are much richer in the rare elements than the large marginal mines.

78 For survey statistics see Dr. Barlow's report, p. 232; and also the successive reports of the survey.

79 As quoted by Barlow, p. 203; in the article quoted, Min. Industry, Vol. IV, p. 460, no palladium is mentioned by the analyst, Titus Ulke.

In regard to the rarer metals it should be said that there is a considerable lapse of time between the mining of the ore and the recovery of the metals after the refining has taken place, so that the returns of the metals are perhaps a year or more behind those of the ores mined.

The quantities of platinum and palladium obtained during the last three years are stated to have been extracted from the accumulations or residues of former years as well as from the mattes actually treated during those years. For this reason, as well as from the comparative leanness in the rare metals of the Creighton ore, the yield of platinum and palladium as well as of gold and silver, is likely to be less in the immediate future. Cobalt is almost entirely removed from the matte during the bessemer process as now carried on in the new smelters of the Canadian Copper Company.

In the statistics given the mines of the Canadian Copper Company must be credited with at least four-fifths of the output of ore and even a larger proportion of the nickel and copper; and the apparent sudden decline in the output in 1904 is explained by the stoppage of the old west smelter while the new one was being completed.

Dr. Barlow has estimated the total value of the metals produced from the Sudbury mines, including nickel, cobalt, copper, gold, silver and platinum, at $52,717,346. On the authority of Mr. Turner he gives the amount of ore produced by the three most important mines up to the 1st of June 1904, as follows:[80]

Stobie mine	419,000 tons.
Copper Cliff mine	366,000 tons.
Creighton mine	310,000 tons.

It is probable that the last mine has now produced more than 500,000 tons. Of the other mines belonging to the company, three, the Evans, No. 2, and No. 3 (Frood) have produced between 100,000 and 200,000 tons. Of mines belonging to other companies the Murray mine produced 62,193 tons, the Blezard about 100,000 tons and the Victoria mine more than 80,000 tons.

It should be mentioned in connection with the statistics given in the main table that the total quantity of the metals reported is the quantity actually recovered, not the total quantity originally contained in the ores. There is a large loss during roasting and smelting of the ores, variously estimated at from 15 to 25 per cent. of the nickel and copper originally in the ore. Messrs. McDonald and Paris of Victoria mine put the loss between green ore and 80 per cent. matte at from 10 to 20 per cent., with an average of about 15 per cent., most of the loss of copper being in roasting, and of nickel in smelting. In other mines of the district good authorities make the loss greater, as much as 25 per cent. in most cases. To get the true contents of the ore from the returns of metals reported it will be necessary then to add probably one-fifth to the percentages given in the table. As the statistics of other countries usually give the metallic contents of the ores as determined by assay, this correction is necessary in comparing our statistics with theirs.

STATISTICS OF OTHER COUNTRIES

The statistics of the nickel production of other countries than Ontario are in a very unsatisfactory state, since there are numerous small mines whose returns seem to be made up in different ways. The most important mining region, New Caledonia, ships almost all its ore raw to various countries of Europe, though a little of it has come to the United States, also; and the returns of the nickel produced in these countries do not agree with the amount estimated in the raw ore. Some portion of the ore probably remains in stock from year to year, so that the output of Europe should follow the New Caledonia returns after a lapse of perhaps a year for ocean transport and the time needed for smelting and treatment.

[80] Ibid., p. 230-1.

The following table is taken from M. Glasser's report on the mineral wealth of New Caledonia, the values being changed from francs to dollars by dividing by five, which slightly overstates them. The tons are metric, slightly less than our long tons, and tons enclosed in parentheses were smelted to matte on the island. M. Glasser thinks the values for 1898, 1899 and 1900 are exaggerated, having been obtained by multiplying the number of tons of moist ore by the value per ton of dry ore.[81]

New Caledonia

Year.	Tons of Ore.		Value.	Tons of Nickel.	
			$		
1875	327		65,400	39	
1876	3,406		340,600	408	
1877	4,377		344,400	525	
1878	155		9,200	18	
1879	....	(Smelted on the island)	....	....	(Smelted on the island)
1880	2,528	(5,058)	101,200	253	(506)
1881	4,069		162,800	407	
1882	9,025	(6,392)	324,800	812	(537)
1883	6,881	(6,768)	248,000	620	(515)
1884	10,888	(7,994)	315,752	871	(637)
1885	5,228	(1,095)	146.384	418	(99)
1886	921		36,840	92	
1887	8,602		515,000	688	
1888	6,616		165,400	530	
1889	21,000	(1,250)	525,000	1,680	(114)
1890	24,590	(1,900)	565,400	1,960	(174)
1891	54,081	(160)	1,135,600	4,326	(15)
1892	35,951		644,700	2,507	
1893	45,613		775,400	3,180	
1894	40,089		561,246	2,795	
1895	38,976		389,760	2,484	
1896	37,467		317,203	2,388	
1897	57,639		403,473	3,458	
1898	74,614		671,526	4,356	
1899	103,908		1,101,425	5,640	
1900	100,319		1,175,400	5,975	
1901	133,676		916,000	7,218	
1902	129,653		915,800	7,045	
Total	960,599	(30,617)	12,576,009	60,693	(2,697)

To conclude the statistics of nickel production, Dr. Barlow's table, mainly derived from the Metallgesellschaft und Metallurgische Gesellschaft (Frankfort-on-the-Main), Aug. 1903, p. 23, for Europe; and from U. S. and Canadian authorities for America, is given below:[82]

WORLD'S PRODUCTION OF NICKEL

(*In metric tons*)

Year.	Sweden and Norway.	Nickel contents of New Caledonian ores.			Total New Caledonia.	Canada.	U. S.	Grand total.	Average price per lb. in New York.
		Germany.	France.	Britain.					
1889	80	282	1,050		1,332	377	114.60	1.904	60 cents.
1890	100	434	1,200		1,634	651	101.27	2,486	65 "
1891	125	594	1,900		2,494	1,830	53.75	4.530	60 "
1892	97	746	950		1,696	1,095	41.84	2,930	58 "
1893	90	893	1,600		2,493	1,807	22.41	4.412	52 "
1894	90	522	1,900		2,422	2,226	4.36	4,742	38 1/8 "
1895	40	698	1,850		2.548	1.764	4.67	4.357	35 "
1896	20	822	1,545	340	2,707	1,541	7.79	4.276	35 "
1897	....	898	1,245	715	2,858	1,813	10.75	4,682	35 "
1898	....	1,108	1,504	1,000	3,648	2,503	5.05	6,156	33 "
1899	....	1,115	1,740	1.350	4,205	2,605	10.22	6,820	36 "
1900	....	1,376	1,700	1,450	4,526	3,211	4.41	7,741	47 "
1901	....	1,660	1,800	1,750	5,210	4,168	3.04	9,381	50 "
1902	....	1,604	1,110	1.310	4,024	4,850	2.61	8,877	47 "
1903	....	1,600	1,500	1,650	4,750	6,348	51.80	11.150	40 "

81 An. des Mines, 10 Series, Tome IV, p. 512.
82 G.S.C., 1904, Part H, p. 236.

A comparison of the total output of nickel in Europe from New Caledonian ore with the quantity of nickel shown by assay of the ores exported shows that the metal refined in Europe almost always falls much below the amount estimated from the assays, and only in one year, 1896, runs beyond it. What percentage of loss there is in smelting the New Caledonian ore is not stated; but the loss during heap roasting should, of course, be avoided, so that the total loss of nickel from the New Caledonia ore should be less than from Canadian ore.

The advance from year to year in the production of nickel from Canadian ore is more rapid than that from New Caldonian ore, so that our mines appear to be gaining ground as compared with those of our rivals.

Minerals of the Sudbury Nickel District

PYRRHOTITE

The characteristic sulphide of the Sudbury mines is pyrrhotite or magnetic pryites, which has already been described in connection with the ore deposits. It is a mineral of somewhat variable composition, running, according to Dana, from $Fe_5 S_6$ to $Fe_{16} S_{17}$, but always containing a little more sulphur than iron. In the Sudbury region it is almost always massive, with little hint of crystal form, though at a number of mines it shows a platy structure suggesting a basal cleavage. Almost the only crystal on record is one obtained by Prof. G. R. Mickle from a miner at Worthington. He describes it thus: "The crystal is evidently a hexagonal prism showing strongly marked basal cleavage; two of the sides are intact and portions of two others remain. The dimensions are 1 3-10 inch, or 32 mm., by ½ inch, or 13 mm.; the weight 26.4 grams; and an analysis of a very small fragment from the crystal gave 2.3 per cent. of nickel."

In general it is stated that the pyrrhotite itself contains no nickel, the metal being carried by enclosed pentlandite; but the above analysis shows that apparently pure and crystalline pyrrhotite may contain it. Experiments in magnetic separation of the finely pulverized ore, carried out by Dr. Barlow, Dr. Dickson and others, show however, that in general the nickel belongs to a non-magnetic mineral, which must be pentlandite.

PYRITE

Iron pyrites, FeS_2, is found at many of the mines, its pale brassy yellow color and its hardness distinguishing it from the previously mentioned sulphides. It occurs as well formed octahedra embedded in the pyrrhotite at the Blue lake and other mines; and cubes of pyrite are found in small fissures with quartz and calcite at Elsie mine. An assay of the latter pyrite showed no nickel. Prof. T. L. Walker has found pyrite with the pyrrhotite from the Murray mine, and believes that nickel is contained in it, replacing part of the iron.[83] His analysis of the pyrite gives 4.34 per cent. of nickel, 39.70 of iron, 49.31 of sulphur, and 5.76 per cent. of insoluble matter.

MARCASITE

The rhombic variety of FeS_2 occurs in several mines and is common in ore from the Worthington offset, especially at openings northeast of the mine. It has not been found in crystal form, though its whitish color and general appearance are characteristic. An assay of the Worthington marcasite by Prof. Walker showed 4.5 per cent. of nickel, and similar results were obtained by Dr. Hillebrand of the U. S. Survey, who found 4.57 per cent. It is probable that pentlandite is mixed with the marcasite.[84] It should be mentioned that the mineral here spoken of as marcasite, shows no crystal forms; so that it is somewhat uncertain whether it is really marcasite or a massive variety of pyrite.

[83] Am. Jour. Sc., 3rd Series, Vol. XLVII, pp. 312-14.
[84] G. S. C., 1890-91, Part SS, p. 116.

PENTLANDITE

The most important mineral belonging to the Sudbury ore deposits is pentlandite (FeNi)S, since in most cases this is the actual nickel-bearing constituent. Though it is supposed to be mixed intimately with all the nickeliferous pyrrhotite, it cannot be distinguished in the ore at most of the mines. The best localities to find it are the Worthington, Creighton and Evans mines, but even in these ores one must often search carefully to see the paler, slightly yellowish patches characterized by a distinct octahedral cleavage. No crystals have been found, but cleavage surfaces of a third of an inch in diameter may be obtained. The ratio of nickel to iron in pentlandite is generally given as variable, but with more iron than nickel, as a rule. The Sudbury pentlandite contains, however, a larger amount of nickel than of iron, as may be seen from the following analyses, No. I by Prof. Penfield[85], Nos. II to IV by Dr. Dickson.[86]

	I.	II.	III.	IV.
Ni	34.23	34.82	33.70	34.98
Co	.85	.84	.78	.85
Fe	30.25	30.00	29.17	30.04
S	33.42	32.90	32.30	33.30
Gangue	.67			
	99.42	98.56	95.95	99.17

MILLERITE

Millerite, NiS, crystallizing in hair-like forms or slender prisms of brass yellow color, is the richest nickel mineral found in the region, since it contains 64.6 per cent. of the metal. It is, however, very rare, though in earlier studies of the deposits it is sometimes referred to as disseminated through the pyrrhotite. It has been found at Copper Cliff by Dr. Peters and Dr. Dickson, the latter considering it secondary after pentlandite. Prof. Walker and the writer found slender crystals of it in the rich nickel ore of the Vermilion mine.

POLYDYMITE

This mineral has been described from the Vermilion mine by Messrs. Clark and Catlett,[87] who gives it the composition Ni_3Fes_5. Analyses are given below, I from authors mentioned, II from Mr. Browne:[88]

	I.	II.
Ni	41.96	36.85
Fe	15.57	18.17
S	40.80	38.43
Cu	0.62	4.47
SiO_2	1.02	
Totals	99.97	98.45

The mineral from the Vermilion mine is gray, very easily tarnished and very soft. On the ore dump it quickly decomposes and loses its metallic lustre Quite large lumps may be obtained almost free from other minerals, though there are generally streaks of chalcopyrite running through it.

NICKELITE OR NICCOLITE

Kupfer-nickel, NiAs, was the earliest source of the metal and is one of the richest ores, containing 43.9 per cent. of nickel. Its pale copper red color and metallic lustre make it a striking mineral, and suggest the presence of copper, from which the original name given it by the German miners was derived. In the Sudbury region it has been found only on the Worthington property and some openings on the same offset to the northeast. The recent finds in the silver-cobalt-nickel mines near lake Temiskaming are often very rich in this mineral.

85 Am. Jour. Sc. (3rd Series) Vol. XLV, 1893, pp. 493-4.
86 Trans. Am. Inst. Min. Eng., Vol. XXXIV, 1904, p. 21.
87 Am. Jour. Sc., Vol. XXXVII, 1889, p. 372-4.
88 Eng. Min. Jour., Vol. LVI, p. 566.

GERSDORFFITE

This mineral is also an arsenide of nickel, NiSAs, but with a larger amount of arsenic and sulphur, so that it contains only 35.4 per cent. of nickel. It is white to steel gray in color and is found associated with nickelite in the Worthington offset, where its name has been given to a prospect, the Gersdorffite mine.

The foregoing minerals are the only nickel minerals proper occurring in the Sudbury district, and apparently the only really important one is pentlandite. The others are never found in the larger mines along the margin of the nickel eruptive, but only along the offset deposits, and usually at a distance from the edge of the norite.

In 1892 Dr. S. H. Emmons described three new nickel-iron sulphides from the Sudbury region, folgerite, whartonite and blueite, with amounts of nickel running from 3.70 per cent. in the last to 31.45 in the first;[89] but later writers hold that his determinations were made from mixtures of minerals. Prof. Penfield considers the folgerite really pentlandite, the blueite nickeliferous pyrite and the whartonite a mixture.[90] Mr. Mickle gives the following account of specimens resembling the blueite as described by Dr. Emmons:

"A peculiar grayish-green bronze-colored, non-magnetic mineral, which tarnishes to a dull bronze, was found by Mr. McVittie on the location where the Gertrude mine now is. The mineral occurred massive, with small crystals of magnetite and specks of chalcopyrite disseminated through it, in a streak about six inches wide adjoining the granite. An analysis of the mineral after removing the magnetite gave the following results:

	Found.	Calculated.
Iron	37.28 per cent.	41.48 per cent.
Sulphur	46.54 per cent.	51.79 per cent.
Nickel	5.95 per cent.	6.62 per cent.
Copper	0.10 per cent.	0.11 per cent.
Insol	9.66 per cent.	
	99.53	100.00

"Assuming the composition to be $Fe S_2$, $Ni S$ and $Cu Fe S_2$:

41.48 per cent. of	iron	requires	47.41	per cent. of	sulphur.
6.62 "	nickel	"	3.65	"	"
0.11 "	copper	"	0.11	"	"

which agrees fairly closely with the amount of sulphur found in the calculated composition, viz.: 51.79 per cent.

"Polishing one side of the specimen shows that the piece is not homogeneous but resembles a porphyry in structure, consisting of a ground-mass with crystals imbedded in it, the crystals having a more yellowish color than the ground-mass. Etching reveals a cellular structure in the ground-mass of alternate light and dark lines somewhat like the surface of meteoric iron or certain steels when similarly treated. Surrounding the crystals is always a dark rim. A similar peculiar grayish-green bronze mineral from Calumet island, Ottawa river, came to my notice, containing 2.64 per cent. of nickel; also one from the ninth level of the Copper Cliff mine, the light colored mineral forming a band in this case. In the examples at hand it does not seem possible to separate the different components in order to analyse each separately. Emmens' blueite with a probable composition of 3.70 per cent. of nickel, 41.01 of iron and 55.29 of sulphur agrees in description with the mixed sulphides just referred to. The percentage of nickel no doubt varies according to the relative amounts of crystals and ground-mass."

We may conclude therefore that the three supposed new minerals should be omitted from the list of nickel-bearing minerals of the region.

CHALCOPYRITE

Chalcopyrite or copper pyrites is always found associated with our nickel ores, though sometimes in small amounts. Pyrrhotite and chalcopyrite are often intimately mixed, as shown in previous chapters, though there is a tendency for the copper pyrites to occur as narrow stringers in fissures of the country rock more often than pyrrhotite,

[89] Eng. Min. Jour., 1892, p. 609. [90] Am. Jour. Sc., Vol. XLV, 1893, pp. 493-7.

as if the copper pyrites were the more mobile of the two minerals. Good crystals of copper pyrites have not been found in the Sudbury region. The composition of copper pyrites, Cu Fe S_2, is constant, and the greenish yellow color and general character of the mineral are familiar. Its irridescent colors when tarnished are striking, and may be noticed on any waste dump at the mines.

BORNITE

The Vermilion mine, which differs so much from the others in tne district, is the only one in which this mineral has been noticed. It occurs with quartz and chalcopyrite, but in small quantities only. Chalcocite, the pure sulphide of copper, also, has been reported from this mine, and native copper was found at the mine in early days.

MOLYBDENITE

Among the minerals at Worthington occasionally a seam of lead gray molybdenite is found crossing the pyrrhotite or partly enclosed in the greenstone, but the amount is very small. It seems to have been a later deposit in fissures cutting the ore and country rock.

GALENA

The only other sulphide mineral in addition to those described above is galena, PbS, which occurs in small amounts as narrow seams with a little quartz or enclosed in the ore without quartz in the Copper Cliff and other mines. The galena may account for a part of the silver always found in assays of matte, the rest being contained in the copper pyrites.

SPERRYLITE

The platinum arsenide, named by Penfield and Wells, sperrylite, (PtAs2), was first obtained from the gossan of the Vermilion mine, but afterwards from the Victoria mine, then called the McConnell property. It was named for Mr. F. L. Sperry of the Canadian Coper Company. As the first natural compound of platinum, it has naturally attracted much attention from mineralogists. It is a tin white, metallic looking mineral in tiny crystals belonging to the isometric system and showing many of the planes found on pyrite. Although the crystals are minute, the largest not exceeding a diameter of 1½mm, or about 1-18 of an inch, the planes are perfect enough to measure a large number of angles.[91] The specific gravity is 10.6, so that it is probably the heaviest mineral known except the native metals. It is generally obtained by panning the gossan of the mines mentioned, where it occurs along with gold.

An investigation of the McConnell property by Mr. Mickle in 1897, showed that sperrylite was generally distributed through not only the gossan but also the solid ore, his assays demonstrating that the platinum is associated with the copper rather than the nickel ores, though some is found in the latter also. The average of six samples of solid ore gave a trifle over 3 dwt. of platinum and a little gold per ton. while pyrrhotite with little copper pyrites gave considerably less than the average. and one example of ore with much chalcopyrite gave 7 dwt. 12 gr. of platinum and a trace of gold. His highest assay showed 1 oz. 3 dwt. of platinum and 3 dwt. of gold from decomposed ore resting on the solid ore.

These results suggest an appreciable increase in the value of the matte from Victoria mine as compared with the other mines in the district, where the amount of gold and platinum in the ore seems to be much less, since these metals and also the silver are concentrated along with the nickel and copper in the matte, and should be recoverable.

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91 Nicol and Goldschmidt, Ueber Sperrylite, Zeitschrift für Kryst., Band 38, Heft 1 and 2, p. 58.

It is of interest to see that Dr. Dickson found quite a large number of sperrylite crystals in almost pure chalcopyrite from the Victoria mine, but not in the other Sudbury ores examined.[92]

Sperrylite may be looked on as the source of the platinum always found in Sudbury mattes, and perhaps also of other metals of the platinum group, though the large amount of palladium recently reported from the matte is not accounted for by the chemical composition as given below, the mean of two analyses:[93]

	Per cent.
Arsenic	40.98
Antimony	0.50
Platinum	52.57
Rhodium	0.72
Palladium	trace
Iron	0.07
Cassiterite	4.62
Total	99.46

Since its description from the Sudbury region sperrylite has been found associated with copper ores in various other parts of the world, so that it can no longer be looked on as a unique or specially rare mineral.

The only other known locality for it in Canada is Copper mountain, British Columbia, where it was found with bornite and copper pyrites by Mr. Jules Catherinet.[93]

Its presence in the nickel ores of Norway is inferred by Vogt, since analyses of matte show that platinum is present, but the actual sperrylite has not been found in Scandinavia.

MAGNETITE AND TITANIFEROUS IRON ORE

In basic rocks, such as norite, magnetite or titaniferous iron ore or ilemenite is always present, and, as might have been expected, these minerals are often disseminated in the nickel ores. Well formed octahedra are common embedded in the pyrrhotite from the Levack mine, and a mass of magnetite five tons in weight was found completely enclosed in the ore at Clara Bell mine north of Copper Cliff. Specimens are readily attracted by the magnet, so that it is not highly titaniferous; and it contains grains of pyrrhotite and chalcopyrite as well as small portions of a green silicate. Titaniferous iron ore was found in small quantities by Prof. Walker in ore at the Murray mine, and many of the thin sections made from the nickeliferous norite contain magnetite surrounded by leucoxene, showing that the unweathered mineral contained titanium.

CASSITERITE

The only other oxide of interest in the nickel ores is cassiterite, or oxide of tin, which was found by Messrs. Penfield and Wells along with the sperrylite from Vermilion mine. The quantity is insignificant, however.

NATIVE METALS

Native copper has already been mentioned as occurring in the Vermilion mine, no doubt as a gossan product. Gold is more commonly found, as small colors, in the gossan at the Vermilion and Victoria mines, as shown in a previous paragraph. In early days it could be panned without difficulty at both localities, and the small amount of gold obtained from the nickel matte of all the mines is no doubt to be accounted for by the presence of free gold in the ore.

Whether the very considerable amount of palladium obtained from Copper Cliff matte occurs native or belongs to some compound resembling sperrylite is not known. A small part of the silver in the matte probably occurs native, alloyed with the gold.

92 Am. Jour. Sc., Vol. I, 1896, p. 112; and Trans. Am. Inst. Mining Eng., Vol. XXXIV, p. 11.
93 Am. Jour. Sc., Vol. XXXVII, 1889. 93 E. M. J., 1905, p. 125.

GOSSAN MINERALS

Almost all the nickel deposits have been acted on by the weather since the glacial period, and are more or less covered with gossan. One might naturally expect to find nickel and copper compounds in the gossan, but apparently these compounds are more soluble than the iron oxides, and up to the present only traces of them have been reported from the region. The gossan consists, apparently entirely, of limonite or hydrous sesquioxide of iron, whose rusty brown color characterizes the deposits. Part of the limonite shows a dark brown, concretionary appearance, while other parts are earthy and yellower. At the Creighton there are in places very pretty concretionary growths in the cavities of the gossan, while other parts have a brecciated appearance, angular fragments of brick red or yellow limonite being cemented by dark brown or even metallic-looking black limonite, the lighter-colored blocks, first deposited as mud, having dried and split, allowing the dark variety to fill the spaces. Some of the gossan deposits might almost be used as iron ores, so completely have the sulphides been decomposed.

When damp there is a peculiar odor connected with the pyrrhotite deposits, coming from the sulphates resulting from the action of oxygen and water on the ore. Ferrous sulphates and doubtless sulphates of copper and nickel, are formed in nature, like the sulphates which appear in cavities in the roast heaps. The only mineral of the kind which has been described is Morenosite or nickel vitriol ($NiSO_4+7H_2O$), which occurs as a greenish-white and pale apple-green incrustation at the Gersdorffite and Worthington mines.[94]

GANGUE MINERALS

In almost all ore deposits the gangue minerals are much in evidence and require description; but in this respect the Sudbury nickel region is an exception. Leaving out of view the rock-forming minerals of the norite and the granite or greenstone of the country rock on the opposite side of the ore deposits, gangue minerals are practically absent in the marginal type of deposit, and play a very inconspicuous part in most of the offset deposits. There are a few later fissures at Creighton, Elsie and other marginal mines in which quartz and carbonates, such as calcite, dolomite and ankerite, are found; but, as they are not connected with the formation of the deposit and do not affect its character appreciably, they may be neglected.

In the offset deposits, such as Copper Cliff and Victoria mine, quartz and the carbonates are more common, but still form only a trifling percentage of the deposit. At the Vermilion and Worthington offsets, however, there is often much quartz with a varying amount of carbonates, suggesting a considerable re-arrangement by circulating water. In some of the offset deposits, as at Worthington and Clara Bell, with the quartz and carbonates blade-like crystals of actinolite are found.

USES OF NICKEL

The metal nickel was discovered by Cronstedt in 1751, in the mineral kupfernickel (niccolite or nickelite), obtained from a cobalt mine in Helsingland, Sweden, and in 1754 he further investigated the substance and described the properties of the metal. The mineral kupfer-nickel looks like copper but does not contain that metal, disappointing the miners, who gave the name in derision; and Cronstedt applied the name to the metal. It was not until 1775 that Bergman prepared the pure metal, however, and even then he doubted its purity because it was attracted by the magnet, which suggested that it contained iron.[95] It was long before a use was found for the metal in Europe, though its alloy, packfong, containing copper, nickel and zinc, had been known to the Chinese from time immemorial; and it is said that "the Bactrian king

94 O. B. O., 1892-3, R. p. 27. 95 Kopp, Geschitche der Chemic, Vol. 4. pp. 156-9.

Euthydemos who reigned about 235 B. C., employed an alloy of nickel for coinage purposes, containing 77.58 per cent. of copper, 20.04 per cent. of nickel and 1.72 per cent. of impurities."[96]

Alloys of nickel were used then long before the pure metal was known, very much as bronze, the alloy of copper and tin, was used for ages before the metal tin was put to use.

Nickel alloys with many metals but its alloys with copper and zinc are the commonest, being used under various trade names, such as German silver, maillechort, argentan, white metal or queen's metal. German silver usually contains 5 parts of copper, 2 of nickel and 2 of zinc; and packfong, mentioned before as a Chinese alloy, contains about 40 per cent. of copper, 15 per cent. of nickel and 45 per cent. of zinc. An alloy of 20 per cent. of nickel with 80 per cent. of copper is much used for casing bullets. For subsidiary coinage an alloy of 75 per cent. copper with 25 per cent. of nickel is used by the United States, Germany, Belgium, Brazil and Venezuela ; and similar alloys are used by other countries.

Within the last few years several nations have adopted pure nickel instead of the nickel-copper alloy for their coinage, and the pure metal has many points in its favor. It does not tarnish and change color like the alloy; but keeps a bright, attractive color; and, as it is harder, the imprint stands wear much better. It is more difficult to counterfeit, since the minting requires more powerful presses. Switzerland was the first country to adopt the pure nickel coinage, in 1883, when 20-centime (four cents) coins were struck. In 1892 Austria-Hungary put in circulation four new nickel coins; Italy came next with 25 centessimi (five cents) coins, but they resembled the silver lira (20 cents) so much that they were withdrawn. In France a bill was passed in 1903 authorizing the issue of 25 centime pieces (five cents), and in 1904 coins of the same value but of different design were issued.[97]

The fineness of nickel used for coinage is from 97 to 98 per cent. pure, and the diameters of the coins mentioned are from 19 to 24 millimeters (from ¾ to nearly an inch), so that they correspond nearly to Canadian bronze cents. The numbers of these coins issued by the nations mentioned already reaches into the hundreds of millions; and they are so preferable in every way to the dull and unpleasant smelling coins of copper or of copper-nickel alloy that other nations may be expected to follow their example.

Why should not Canada, the producer of half the nickel of the world, replace her ugly cents by clean, untarnishable, nickel coins, almost as handsome as silver and much more durable? Canada is presently to have a mint, and it should begin its work by coining one-cent and five-cent pieces of pure nickel; making use of a distinctively Canadian metal.

A new use for pure nickel, which may grow to be of great importance is in the manufacture of Edison's latest storage battery, which is very much lighter than the old lead storage batteries.

The uses of pure nickel, other than for coinage, are not at present of great importance, though various small articles are made from it, but its use in plating iron or steel and zinc is very wide-spread, on account of the untarnishable white surface it gives; and nickel plated articles are in use everywhere.

NICKEL STEEL

The value of nickel as the pure metal and in its alloys with copper, zinc and other metals, where the percentage of nickel is considerable, depends largely on its white color, and the fact that nickel has a very high power of impressing its whiteness on alloys in which other metals, such as copper, are in preponderance.

[96] G. S. C., 1904, part H, p. 524; where Dr. Barlow refers to Austen's Historical Sketch of Nickel as his authority.

[97] See an interesting article in The Iron Age, Vol. 75, No. 14, pp. 1175-6.

In its alloy with iron and steel the usefulness of nickel turns on the great improvement in strength and other properties which it imparts to the alloys, even when present in quite small amounts. It is singular that iron and nickel, with their close relative cobalt, should be so regularly divorced in ordinary ore deposits, for the three form a natural group of metals very much alike in many of their properties, and probably once intimately associated. In meteorites iron plays the largest part, but always contains a small percentage of nickel and a much smaller percentage of cobalt. In a few examples of basic eruptive rocks we find the native metals associated also, but iron ores are almost always devoid of nickel or cobalt. The ores of iron have undergone processes which have removed the nickel, probably because of the greater solubility of its compounds, if the two metals were associated in the beginning, as seems likely. One of the most striking advances in metallurgy of late years has been the restoration of the partnership of iron and nickel by the production of nickel steel.

The idea of using a nickel-iron or steel alloy was suggested by more than one scientific man, and samples of such an alloy were made and more or less experimented with long ago, as may be seen from the following extract from Mr. Albert Ladd Colby's valuable paper on Nickel Steel: its Properties and Applications.[98] Searching through proceedings of scientific societies for the past 80 years, he has found a number of references to the subject.

In 1822 Stodart and Faraday published their experiments made at Sheffield in the alloying of nickel and iron. A little later Berthier made some similar experiments in France.

"In 1830, Wolf, of Schweinfurt, Germany, put some nickel-iron alloys on the market, which he called 'Meteoric Steels.' They were damasked, and Liebig comments on their magnificent appearance in a note in the *Annalen der Pharmacie*, and states that this alloy is destined to be developed in the near future.

"In 1835 Fairbairn published some experiments undertaken to determine the strength of some alloys of nickel and iron similar in composition to meteoric iron.

"At the Exposition held in New York, in 1853, Philip Thurber exhibited several samples of nickel steels produced from a nickeliferous limonite.

"In 1858 Sir Henry Bessemer made an experimental 3 per cent. nickel-iron alloy, with a view to making what he termed 'Meteoric Iron Guns.' He did not, however, pursue the subject, nor publicly refer to the matter until 1896.

"Percy in his Metallurgy, published in 1864, refers to experiments conducted by Richardson in his [Percy's] laboratory on nickel-iron alloys varying from 1 to 50 per cent. in nickel.

"In 1870 Alex. Parkes, of Birmingham, took out several patents for the production of alloys of iron and nickel; in 1883 John Gamgee made nickel-iron alloys in Connecticut; in 1884 A. M. Clark, of London, patented the manufacture of a malleable ferro-nickel.

"In 1885 ferro-nickel was manufactured at Marbeau's works at Montalaire, France, under the supervision of Bertheault.

"In 1887 highly carboniferous nickel steels were made experimentally at the steel works at Imphy, France; and in 1888 and 1889 several French and English patents for the manufacture of nickel steel, and its applications, were granted to Marbeau, Schneider, Riley and Hall.

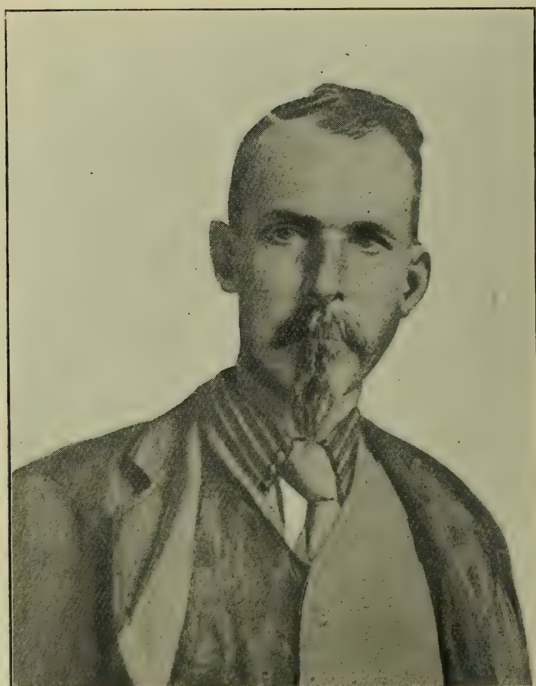
"It is therefore evident that the advantages of alloying nickel with iron and steel have been known for some time. The credit of making the first systematic series of practical tests on nickel steel belongs, however, to Mr. James Riley, then of Glasgow, whose elaborate paper on 'The Alloys of Nickel and Iron' was read by him on May 8 1889. From a discussion of this paper it appears that J. W. Hall, of Sheffield, had been working on similar lines, but his results had not been publicly put on record. Mr. Riley's paper gave the impetus to the introduction of nickel steel in a commercial way."

It should be mentioned that nickel prepared by the Mond company is now being used in the manufacture of armor plates for the British Government, so that the former prejudice in the Old Country against Sudbury nickel has been overcome.

The importance of nickel steel to the Province of Ontario as an outlet for its nickel was early recognized by the Bureau of Mines, and papers on the subject may be found in the volumes for 1893 and 1894[99]; showing its value for various purposes, especially in the manufacture of armor plate.

98 Proc. Am. Soc. for Testing Materials, Vol. III, 1903, pp. 141 and 2.
99 1893, pp. 147-163; 1904, pp. 182-198.

Since that time almost all navies have been clothed in nickel steel armor, and there have been many applications of the alloy to other purposes, such as the bicycle manufacture, the making of shafts for steamships and the making of steel rails on curved parts of railways where there is heavy traffic causing great wear. No doubt the great improvement in the strength, elasticity, etc., of steel imparted by 2 to 4 per cent. of nickel would have caused its use on the large scale in structural steel if the cost of the metal had been lower. Further instances of new uses for this alloy will be found in Mr. Colby's paper[100] and in Dr. Barlow's report.[101]

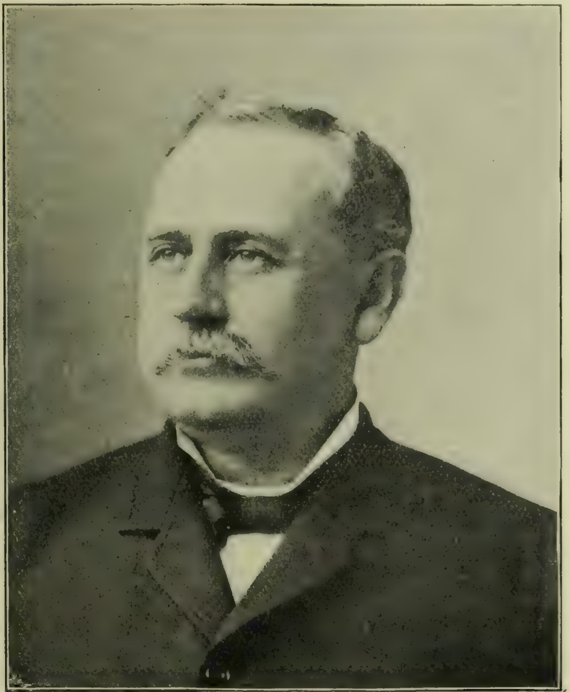


Henry Ranger, Sudbury, a well-known prospector of the nickel field.

APPENDIX:

Nickel and Nickel Steel

Although much has been written on nickel steel, the subject is of sufficient importance to Ontario to warrant taking it up here, particularly as some new documents in the history of the subject have been secured, through the kindness of Mr. S. J. Ritchie, of Akron, Ohio. Mr. Ritchie was specially interested in the development of our nickel deposits as one of the early owners of nickel properties in Ontario, and was



S. J. Ritchie, Akron, Ohio, a pioneer in developing the Sudbury nickel field.

instrumental in drawing the attention of the Navy Department of Washington to the value of nickel steel in armor plates. He has been good enough to provide copies of the correspondence on the subject, part of which is here reproduced. The work of John Gamgee in applying nickel-iron or steel has apparently been somewhat overlooked. It will be observed that his idea of using it was derived from the properties of the nickel-iron meteorites. The report of Sir Charles Tupper, then High Commissioner for Canada in London, is of special interest. Mr. Ritchie's communication dealing with the origin and early history of the nickel industry in Ontario and Gamgee's experiments at the Washington Navy yard is as follows:

100 Am. Soc. for Testing Materials, Vol. III, pp. 163 and 165. 101 G. S. C., 1904, Part H, pp. 227-8.

Nickel and Yellow Fever

" The discovery of nickel and the origin of the nickel industry in the Sudbury district is in itself quite unique. My first knowledge of nickel, as an alloy with iron or steel, was in 1876. In that year, I think, yellow fever was epidemic in the cities of the lower Mississippi and Gulf states. It is well known that the germs of this disease are killed by frost. At the date named, I was spending a good deal of time in the city of Washington. At the same hotel, and occupying the room adjoining my own, was one of the most fertile-brained Englishmen I ever met, whose name was John Gamgee. He spent much of his time in my room. He was resourceful in experiment and demonstration, but his imagination went far beyond his laboratory tests. He had remedies for tuberculosis in animals and for yellow fever among human beings. His remedy for yellow fever was the building of a large refrigerator ship on which a frost temperature was to be maintained. This ship he proposed to move around to the different cities where the fever existed, and to take the patients on board where they were to be cured by the frosty atmosphere.

'He laid his plans before the United States Senate Committee on Epidemic Diseases, and convinced that Committee of the feasibility of his enterprise. He asked me to go with him to that Committee, several of the members of which I was very well acquainted with, and aid him in securing a government appropriation for the building of his refrigerator ship.

"I did succeed in getting a promise from the Committee that an appropriation of $250,000 would be given to Gamgee, provided he could actually demonstrate to the committee that he could successfully produce and maintain the proper temperature, and for the purpose of making the necessary experiments and demonstrations a large room and all the necessary machinery was placed at his disposal in the Navy Yard at Washington.

"He erected a large machine in the Navy Yard buildings built by the Wilmington Car Works of Delaware. It must be remembered that all this was 28 years ago, when cold storage was not so well known as now.

"Of course Gamgee had to use liquid ammonia in producing his frosty temperature, and this substance, as is well known, will generate gas at a temperature much below the zero point. Gamgee conceived the Utopian idea that he would drive his machine with the gas generated from his liquid ammonia by the heat of the atmosphere, and that the gas would part with its heat in the labor of operating the machine and after having done its work would become reliquefied and be ready again by the aid of the heat in the atmosphere to generate more gas, and again start upon a second round of effort the same as the first. In other words he was within one step of perpetual motion, the lacking step being the wearing out of the machine.

"Numerous members of the Senate and engineers of the army were on hand to see Gamgee's ammonia engine operated. Right here Gamgee struck a snag. He was able to generate so great a pressure from the ammonia gas that the ordinary cast iron would not contain it, and he set about making all sorts of alloys to strengthen the iron and to overcome its porosity. They all failed. The object of the enterprise and the whole manner of conducting the experiments were so novel to me that I spent several weeks with Gamgee helping him in any way I could. After a series of experimental failures he one day said to me, 'Ritchie, did you ever notice the meteorites at the Smithsonian Institution? I want you to go with me and see them.' I told him that I had many times seen them and knew just how they looked. He said, 'Well, we have no metallic iron on earth produced by nature in that form, and these meteors have all fallen from the skies, or have come from some other world. They nearly all contain nickel and are the closest grained metal we have. To-morrow we will send over to Philadelphia and get some nickel and we will try this metal as an alloy with iron, and see if we can imitate nature in duplicating the meteorite, as we are trying to imitate nature in the production of artificial cold for the yellow fever patients.'

"We did send over and get some nickel and at once commenced our experiments by adding one-half of one per cent. of nickel to the molten iron in the crucible, and increasing each separate mixture by an additional one-half of one per cent. of nickel, until a limit of thirty-six per cent. of nickel as an alloy with the iron had been reached. We thus had some seventy-two separate pieces of iron and nickel alloys all carefully marked. When an alloy containing some eight per cent. of nickel had been made we tested it, as we really did all the other specimens, but I particularly recall that containing eight per cent. of nickel. It was so hard that neither the file nor the cold chisel would affect it. We put it upon the anvil, and with a ten-pound sledge I expected to be able to break it into pieces, but although I then had seventy-five pounds less flesh than I now have, and several times as much muscle, I could not even mark the alloy with the heaviest blow I could strike with this ten-pound sledge, not to talk about breaking it. After we had made many tests with the several different percentages of the alloys, Gamgee threw up his hands and shouted, 'Eureka! I have found at last an alloy strong enough and hard enough to resist anything and close enough in texture to resist the escape of any form of gas.' The members of the Senate committee were again brought back to the Navy Yard to see these specimens of nickel alloy. The way now seemed clear for Gamgee to secure his promised $250,000 and to proceed with the building of his refrigerator ship which would be used as a hospital ship for the cure of yellow fever patients.

"Gamgee, like most abnormally developed geniuses, had no place in his make-up for such humdrum routine efforts as financial operations. In short, he had no other financial abilty than the abilty to get into debt without any ability to get out of debt, He never even took out any patents upon these alloys of nickel and iron and steel. He failed to agree with the Senate committee on the cost and management of his proposed ship, and thus failed to secure the $250,000 appropriation. In the language of diplomacy, the incident was closed, and I lost sight of Gamgee, and all the interesting experiments and experience passed out of my mind.

"All this was seven years before I had ever seen Canada.

Opening the Sudbury Field

"In 1882 I became interested in building the Central Ontario Railway to open up and develop the iron fields of North Hastings. When the road was built it was found that these iron ores contained so much sulphur as to be unmarketable, and I commenced a systematic search for other mineral deposits, which, under the terms of the charter of the railway, the railway could own and operate and by such conveyance of property I might support and protect the securities of the railway.

"In this effort to secure something for the railway I had a considerable search of the country made by the local inhabitants and others from Nova Scotia to Port Arthur. I went to the Geological Museum at Ottawa and examined specimens of every kind of ores from every part of the country. Among the many specimens examined at this museum I found some copper ores taken from a cut in the Algoma Branch of the Canadian Pacific Railway at what is now Worthington Station, and other specimens taken from a cut in the main line of the Canadian Pacific Railway at what is now known as the Murray mine, about three miles west of Sudbury. These samples I had analyzed and found them very rich in copper.

"I at once proceeded to have these deposits located. While so doing I found that W. B. McAllister and J. H. Metcalf of Pembroke, Ontario, had located and taken up a number of these deposits in this Sudbury mineral belt. Among these was what is known as the Copper Cliff mine, the Stobie mine, the Lady Macdonald mine, the McArthur mine and the Creighton mine, the latter not at that time yet deeded to them, and several other deposits not named. With the exception of a small mine, known as the Evans mine, and a little ore taken from what is known as the Frood mine, which I purchased shortly after the purchase made from McAllister and Metcalf, these

mines thus purchased from McAllister and Metcalf in the summer of 1885 have furnished all the ore mined by the Canadian Copper Company from 1886 to this day, and are still their sole source of supply.

"Immediately after the purchase of these mines, or rather deposits, from McAllister and Metcalf, in 1885, and some other properties from individuals, in 1886, including some purchased from Rinaldo McConnell, James Stobie and R. J. Tough, I made application to the Ontario Government, through J. D. Evans, the engineer of the Central Ontario Railway, for large additional locations. Under this application Mr. Evans located 97,000 acres; however, those who were afterwards associated with me did not agree with me in keeping this area of land, but wished it to lapse, which it was allowed to do.

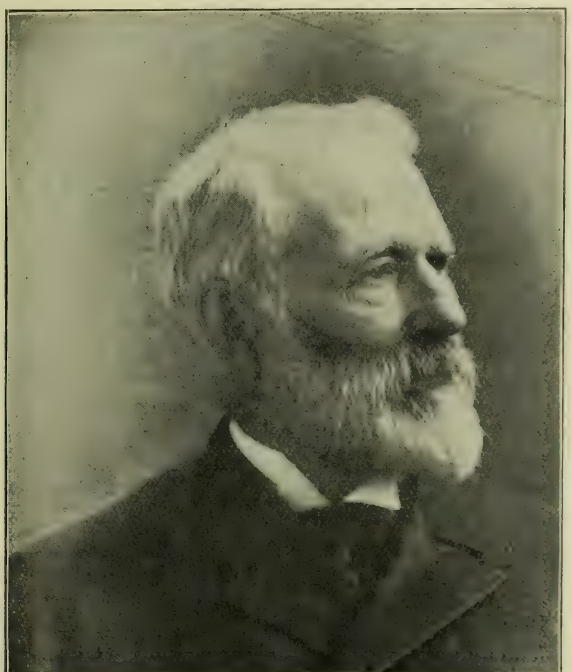
"In January 1886, I organized at Cleveland, Ohio, under Ohio charters, two corporations, one known as the Canadian Copper Company with a capital of $2,000,000, later increased to $2,500,000, and the other known as the Anglo-American Iron Company with a capital of $5,000,000.

"To the Canadian Copper Company my wife and self deeded the lands purchased from McAllister and Metcalf, Rinaldo McConnell and others, and to the Anglo American Iron Company the late James McLaren, the late H. B. Payne of Cleveland and my wife and self deeded the 85,000 acres of land along the line of the Central Ontario Railway, and for the opening up and development of which the Central Ontario Railway was built. The interest of the late William Coe of Madoc in these Hastings county lands was conveyed to the Anglo-American Iron Company at a little later date.

Discovering the Nickel

"In 1886 some work was done upon the property of the Canadian Copper Company at Copper Cliff, and in 1887 a shipment of some 1,200 tons of this ore was made to the works of the Orford Copper Company at Constable Hook, New Jersey, in the harbor of New York. While the chemist of the Orford Company was making his analysis of the product of the furnaces from these ores he found a metal with which he was not familiar, and after numerous tests he found this substance to be nickel. I happened to be in the laboratory when this discovery was made. Robert M. Thompson, the president and owner of these works, was also there. The discovery of this nickel in these ores by the chemist of the Orford Copper Company was alike unexpected news to both Thompson and myself. We had no suspicion that they were anything but copper ores. This discovery changed the whole situation. We found we had a great nickel deposit, instead of a great copper deposit, or, to be more correct, we had a great nickel and copper deposit. As the world's annual consumption of nickel was then only about 1,000 tons, the question was what was to be done with all the nickel which these deposits could produce I at once recalled the experience I had with John Gamgee at the Navy Yard at Washington, ten years previous to this time, and it occurred to me that nickel could be used with success in the manufacture of guns and for many other purposes as an alloy with iron and steel. I wrote to the famous gun maker, Krupp, at Essen, Germany, telling him of the Washington experiments, and asking him about his use of it in the guns which he made. I received an answer from him through his New York agents treating the matter lightly, and refusing to believe that there was any sufficient quantity of nickel in the world to warrant experiments looking to any extended use of the metal. The question of these alloys was, however, brought by Krupp, or someone representing him, to the attention of the Iron and Steel Institute of Great Britain, and that Institute appointed one of its members, James Riley, the manager of the Steel Company of Glasgow, to conduct a series of experiments with this alloy, and report at the next meeting of the Institute. This he did with great care and exactness, and embodied his experiments in a report dated in May, 1889. This report I showed to General Tracy, then Secretary of the United States Navy in the summer of 1889, just as I was leaving for Europe. He read

the report and grasped its far reaching importance within an hour or two after receiving it, and said that the Navy Department wished to send an expert representative of the Government with me to any and to all places which I might visit in Europe in the interest of this nickel-steel alloy.[102] As I was going to Europe for that purpose, Lieutenant B. H. Buckingham of the U. S. Navy, then connected with the office of the U. S. Ambassador at London, was appointed to accompany us wherever we might go in Europe in this interest. Sir Charles Tupper, then the Canadian High Commissioner in London, was also designated by Sir John A. Macdonald to accompany us in the interest of Canada in this enterprise to find out whatever might be learned in Europe about the uses and the alloys of nickel with steel. Sir Charles Tupper and Lieutenant B. H. Buckingham of the U. S. Navy did go with us to visit the works of Krupp in Germany and the principal establishments of Great Britain and France, and the famous Rio Tinto mines of Spain. Sir Charles made a report to Sir John A. Macdonald, and Lieutenant Buckingham made a report to the Secretary of the United States Navy of what we had been able to see and find out. We spent two days in the works of Krupp at Essen, and were shown every possible courtesy. Upon our return Secretary Tracy



Genl. B. F. Tracy, who introduced nickel-steel armor plate into the United States Navy.

ordered a nickel-steel armor plate made at the famous Creusot works in France, and also a plain steel plate made at the same works, and a plain steel plate made at the works of Cammel & Company at Sheffield, England, such as was then used on British vessels of war. These plates were brought to the Government proving grounds at Annapolis, Maryland, and set up side by side and fired at, at short range, by eight-inch guns.

"The victory of the French nickel-steel plate was so complete over both the French and English plain steel plates that the trial and tests were heralded by telegraph and cables all over the civilized world.

102 A synopsis of Mr. Rielly's paper entitled "Alloys of Nickel and Steel," was published in the Report of the Royal Commission on the Mineral Resources of Ontario (1890), pp. 383-387.

"Tracy, by this Government test, sent all the common steel armor plates to the junk heap, and completely revolutionized the offensive and defensive efficiency of the navies of the world. Scarcely had the sound of the guns at Annapolis died away before Congress in an hour, at the request of the Secretary of the Navy, General Tracy, voted an appropriation of $1,000,000 to purchase nickel matte at Sudbury to be used in the manufacture of nickel-steel armor plate for the U. S. Navy. This million dollar appropriation by the U. S. Government and the use of nickel in steel advertised the Sudbury mines over all the commercial world. It saved the Canadian Copper Company from the expense of making any tests of nickel alloys, for they were all made by the Government. In short, the Government's action through the Secretary of the Navy put a new enterprise upon its feet. The Government changed the then existing contracts with the Bethlehem Steel Company from plain steel plates to nickel-steel plates. It entered into contracts with the Carnegie Steel Company for the manufacture of nickel-steel plates under which contracts millions of dollars were expended in building the famous Homestead works. The small experiments in the Washington Navy Yard in 1876 have grown to the proportions of covering every first-class war ship in the navies of the world.

The International Nickel Company

"On December 7th, 1901, an optional contract was entered into between four of the directors of the Canadian Copper Company and the Anglo-American Iron Company and Robert M. Thompson on behalf of himself and associates, the associates being Captain DeLamar, E. C. Converse and Charles M. Schwab, under which contract the directors of the Copper and Iron Co's undertook to sell, and Thompson and his associates undertook to buy, a controlling interest in the stocks of these two companies. It was a part of this contract, that Thompson and his associates should form a company under the laws of New Jersey to be known as the International Nickel Company, and that this company should receive from the purchasing syndicate the stocks of the Canadian Copper Company and the Anglo-American Iron Company purchased under this optional contract of Dec. 7, 1901, which optional contract was accepted by Thompson and his associates on February 28, 1902. The stocks of these corporations turned over by the purchasing syndicate were deposited with the New York Security and Trust Company as a basis for the issuance of the bonds of the International Nickel Company. I should perhaps have said that in carrying out this contract of Dec. 7, 1901, the International Nickel Company, under a New Jersey charter, was organized under date of April 1st 1902, with a share capital of $24,000,000, and a bonding privilege of $12,000,000.

"A mortgage was executed by the International Company under date of April 1st, 1902, securing the bonds of the company upon the stocks of the constituent companies deposited with the New York Security and Trust Company, who were the trustees for the bondholders of the International Company. The Nickel Syndicate also purchased the stocks of the Nickel Corporation of London, a New Caledonia concern, and one of Whitaker Wright's enterprises, and also the stock of another small French company, known as the Societe Minière Caledonienne. The aggregate of all the stocks, Canadian and New Caledonian, with the stocks of the Orford Copper Company, and the stock of Joseph Wharton's small plant at Camden, near Philadelphia, amounting to about $10,000,000, were deposited with the New York Security & Trust Company, and $10,300,000 of the authorized $12,000,000 of bonds and $18,000,000 of the authorized $24,000,000 of stock of the International Nickel Company were issued against these stocks thus deposited with the Trust Company. The stocks of all the constituent companies belong to the International Nickel Company. The New Caledonia companies are not and have not been operated by the International Nickel Company. No report is made of them in the reports of that Company.

The Canadian Copper Company now owns some 16,000 acres of land and the Anglo-American Iron Co. some 85,000 acres. The International Company operates in Canada wholly through the constituent companies.

"Neither Gamgee nor any other man invented nickel-steel. It is a discovery, not an invention, and it is probably the only instance in this world where any form of manufacture is carried on after a formula coming from the heavens or some other world other than our own.

"There is a very beautiful specimen of nickel-iron meteorite in the Geological Museum at Ottawa, weighing about 400 lbs. It contains something over six per cent. of nickel, and was found on a farm in Hastings county, and for years was used by some untidy farmer to hold his barn-door closed. It never occurred to this farmer that this lump of metal was a manufacture of the skies. I have several times offered $500 for this meteorite, but of course the Museum would not sell it. Perhaps I ought to add that as soon as Riley's report had been read by Secretary Tracy in 1889 and I had given him a report of the experiments at the Navy Yard in 1876, he put the whole machinery of the Department at work over the United States and Europe to find Gamgee. I, myself, while in Europe, had the directories of all the principal cities of Great Britain examined, but neither the Navy Department nor myself could find him. About a year later I was in the second-hand bookstore at Washington, owned by H. W. Lowdermilk, a place where Gamgee formerly spent much time, and I told the proprietor of the efforts of the Navy Department and myself to find Gamgee, and that we had concluded that he must be dead. He said he was not dead, and gave me his address in London which was within half a block of the office of the Canadian High Commissioner. I then wrote to him and received two or three letters from him. He was still in the field of invention, experiment and discovery. If there had been earlier laboratory tests or experiments with nickel and steel than those of the Washington Navy Yard in 1876, neither Gamgee nor myself knew anything about them. We followed the meteorite and there is not the shadow of a doubt that the reconstruction of the American navy, clad with nickel-steel armor plates, was the direct result of these Washington Navy Yard experiments following the formula of the meteorite, although the experiments were farther carried out by the Iron and Steel Institute of Great Britain under the direction of James Riley ten or twelve years later. Gamgee is now dead, but General Tracy is alive and well, and I have no doubt would fully confirm every statement here made.

"Whatever might have been the ultimate development and outcome of the Sudbury nickel-copper deposits in other hands, and by other parties, one thing is very certain, that had it not been for the development of sulphur in the Hastings county iron ores, which made them unsaleable, thus depriving the Central Ontario Railway of the principal tonnage which it was built to carry, there never would have been any Canadian Copper Company or any Anglo-American Iron Company, or any International Nickel Company, and as the Washington Navy Yard experiments with nickel. iron and steel following the formula of the meteorite had already passed out of mind before the discovery of nickel in the Sudbury ores, there would, in all human probability, have to-day been no nickel-steel clad American navy, and this would mean that there would have been no nickel-steel clad navy in the world. From the sulphur in iron ores in Hastings county, Ontario, aided by the composition of the meteorite, has grown all the nickel and nickel-steel industry of this hemisphere as well as very much of like industries in the old world."

Mr. Gamgee's Recollections

A letter from Mr. Gamgee to Mr. Ritchie in reply to a communication from the latter gives some further details regarding the early experiments carried on in the Navy Yard at Washington. It is dated London, March, 1893:

"S. J. Ritchie, Esq., Dear Sir: I have to thank you for your kind letter of the 28th of February, which duly reached me this morning. I have, of course, noticed with interest the progress made in utilizing the iron and nickel alloy.

"The difficulties we encountered in the castings for the ammonia engines and pumps at the Washington Navy Yard, in spite of the skilled workmen in the foundry,

led to various devices to overcome the porosity of the metal, and one day I was much surprised at seeing pure tin run into some large blow holes. The loss incurred from having to discard cylinders on which much work had been expended suggested to me that some more rational and scientific method of providing a sound metal should be attempted. Suddenly the compactness and solidity of meteoric iron struck me, and I determined on trying very small proportions of nickel, beginning with one per cent. up to three per cent. Large quantities rendered the metal too hard for the tools, and we resorted to the process of annealing, in some cases. With the advantage of testing machines of the Navy Yard we soon determined that we could double the tensile strength of the best cast iron, and perhaps you know how how we had to secure uniformity of the alloy. We attempted to melt the nickel in lumps in the melted iron as it ran from the cupola, and the resultant casting was of unequaled hardness, tools being broken when striking against a knob of the nickel that had not been melted. We therefore first melted the nickel in a crucible and I shall never forget the effect as seen in our first trial of dropping the small proportion of melted nickel into the ladle. The surface of the melted mass became covered with particles of dirt or dross, which was skimmed off, leaving a perfectly pure mass, which we ran into moulds, and yielded castings that readily resisted, on testing, very heavy hydraulic pressure. I regret that I had no opportunity of introducing the metal for other purposes, but the experiments were so public and excited so much interest in the Navy Yard that I am not altogether surprised to find that at least some one turns up to give me credit for the suggestion. . . . . . ,

"We rolled some plates, and many experiments were made with various quantities of nickel to obtain a metal that would not rust. I regret that I lost my original notes, but it is somewhat strange that the fact of the first experiments having been conducted by me in the Washington Navy Yard has never before been noticed, as there should be records by the officers who had charge of the Ordnance Department and testing machines.

"I have used the metal from time to time since, and one firm of ammonia machine makers in America have continued to make nickel-iron castings since I first introduced them in my methods in 1880. I am now deeply engaged with the final results of 15 years' labor in reaching the automatic condensation of all vapors. By this means I can run ice machines without using condensing water, and dispensing almost entirely with fuel. I am building a low temperature engine which will demonstrate the soundness of the views I entertained in the days when you remember me working in the States, and which were derided except by that most able of chief engineers, Mr. Isherwood, and a few other choice spirits. I am running steam engines working steam at 212° Fahrenheit, as stated in the circular, and I would give almost anything for more help and intelligent co-operation in the States and Canada. I sadly need help. My experiments have been costly and protracted, and whilst there is abundant ground for hope now at a good turn in affairs, yet I can assure that it is not easy to overcome the prejudices of the engineers anywhere. Might I ask in what position you are in the Navy Yard, and how you came to know so much of my wandering? I shall be glad to hear from you again at your earliest convenience, and remain, yours faithfully, JOHN GAMGEE."

"[NOTE.—The Gamgee experiments at the Navy Yard were not carried on under any inspection or oversight on the part of the government, and therefore the Navy Department kept no records of them, as the superintendent of the yard informed me, when I went to hunt up the records of these experiments and tests, in 1887.— S. J. R."]

Sir Charles Tupper's Report

The report of Sir Charles Tupper, referred to by Mr. Ritchie, giving the results of his investigations into the use of and probable demand for nickel in Great Britain and continental Europe, is interesting enough to warrant its being published in full. Sir John A. Macdonald's letter introducing Mr. Ritchie, which is also given, shows

that even at this early stage he recognized the importance both to Canada and the empire at large of the Sudbury nickel deposits. Unfortunately his hopes of interesting the Imperial authorities in the matter were not destined to be realized. Sir John's letter to Sir Charles is dated 11th July 1889:

"My Dear Sir Charles Tupper: Our friend S. J. Ritchie, of Akron, Ohio, whom you know, is about to proceed to England for the purpose of calling the attention of the British public to our mineral wealth in Canada. He desires especially to submit to Her Majesty's Government the important fact that in Canada, especially in the region of Sudbury, is the largest deposit of nickel in the world. This metal is wanted particularly as an alloy to make an important gun metal, and its extended use will be of great advantage to the Dominion. Will you kindly put Mr. Ritchie in communication with the Secretary, both of the Army and Navy, as well as, if necessary, with Lord Salisbury. It is said that the use of nickel will tend to revolutionize the art of gun-making, and that experiments, both in England and Germany have proved this to be the fact, so you see the importance of the matter. I hope you will give Mr. Ritchie all the aid and countenance in your power. Believe me, yours very truly, John A. Macdonald."

Following is Sir Charles' report, dated London, November 1889:

"To Sir John A. Macdonald, Premier, Ottawa. My Dear Sir: On the 20th of August last Mr. S. J. Ritchie brought a letter from you to me requesting me to aid him in bringing to the notice of the British War and Navy officers the importance of the recent discovery in metallurgy consisting of an alloy of nickel and steel said to have very valuable properties for the manufacture of guns and armor-plates for warships. He also had letters from the Secretary of the Navy at Washington addressed to the American Minister here requesting his good offices in the same direction. He likewise had letters from the Commodore of the United States Navy directing the naval attache of the American legation here to accompany him to all places he might visit in Europe and to investigate the progress and results thus far obtained from the use of this metal. He asked me to accompany him and to see for myself the importance not only of this metal but of the whole iron, steel, copper and nickel interests, and to see the mines and the ores from which they are manufactured, as he said they would visit the largest mines and manufactures of the world.

"In compliance with this request I left London on the 24th of August in company with Mr. Cornell, Mr. Oviatt, Mr. Ritchie and Captain Buckingham, the representative of the United States Navy. We proceeded to Paris, which is the headquarters of the New Caledonia Nickel Company. This company has up to the present time produced nearly all the nickel consumed in the market of the world, and of course has entirely regulated the market for this article. The Society, as it is called in France, is known as 'Le Nickel.' It is a corporation with $12,500,000 capital. They employ 1,450 men, they reduce the ores upon the ground to a matte. They are then shipped to Havre in France, to Birmingham in England, to Glasgow in Scotland, and to Iserlohn in Westphalia, Germany, at each of which places the company have refining furnaces for the treatment of these mattes and converting them into fine nickel. The ores contain no other valuable mineral than nickel. The company produce cobalt, but this is principally obtained from ores containing but little nickel, the ores are not easily reduced or refined, and it is said that the cost of producing fine nickel to them is forty cents per pound. We called upon this company at their office in Paris and found them quite unwilling to believe that there were any nickel deposits in the world outside of their own of any importance. They, however, wanted the Canadian Copper Company to agree to let them have the control of their entire product. These mines belong almost wholly to the Rothschilds. A Frenchman of the name of H. Marbeau is the patentee of the alloy known as ferro-nickel. It is a composition varying from one to twenty per cent. of nickel with steel or iron; usually about three per cent. of nickel is used.

"A company has been formed in Paris under the name of the 'Ferro-Nickel Company' for the manufacture of this material. The patentee Marbeau is its president. The real owners are probably the Creusot works located at Creusot in France, and owned by Schneider & Company. This establishment is to France what Krupp is to Germany. They are a great establishment, employing over 15,000 men. We also called upon the Ferro-Nickel Society at their office and saw their product at their salesrooms. We found the president enthusiastic over his discovery, and the wonderful results he has been able to produce. He was much elated over the discovery of a new and large body of nickeliferous ore and pressed the members of the Canadian Copper Company who were there, in the strongest possible manner, to give their company sole control of their product; said that they could use it to any extent to which it might be produced as an alloy with steel. The Canadian Company, however, declined in either case to make any contracts with either the Nickel or Ferro-Nickel Companies.

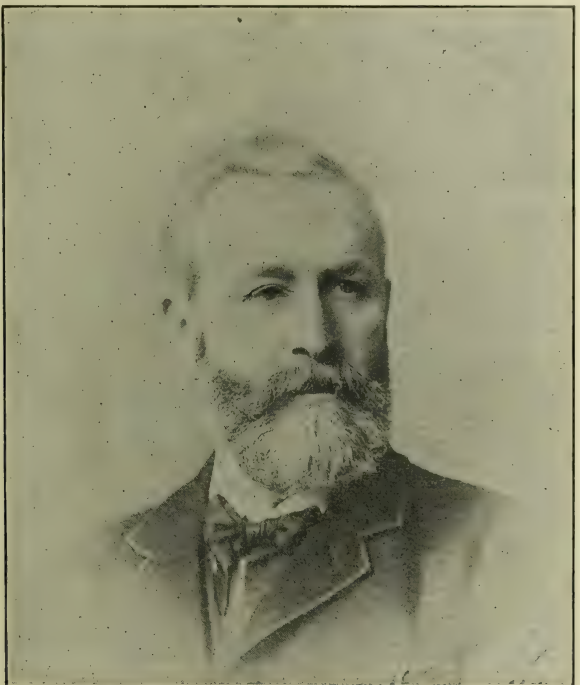
"From Paris we went to Hamburg in Germany to which point the Sudbury Company had shipped some of their product. Parties from Vienna, who are largely engaged in the manufacture of nickel came to this place to meet us in connection with the Hamburg people. They wanted to contract with the Sudbury people for a period of ten years for the delivery of a large amount each year. They offered to buy the matte as now produced at Sudbury and to erect refining works at Hamburg for the refining of the nickel and copper contained in them. They pressed the matter very earnestly. These people own the largest manufactory of German silver-ware there is in Europe, their works are located at Berndorf. Both the Hamburg and Vienna people offered to send a Mr. Krupp, who is one of their firm, and a nephew of the great gun-maker, to see the property, and learn if some arrangements could not be made by which they could become identified in the ownership of these properties. It is likely this visit will be made in the spring.

"From Hamburg we all went to Berlin. The nickel works at that place were a small affair and we saw little of their working owing to the secrecy which is everywhere observed in the refining of this metal.

"From Berlin we went to Essen where are located the great works of Friedrich Krupp. These are the largest iron works in the world and are under the sole control and ownership of one man—Friedrich Krupp. These works were started by his father, who died a year or two ago, in a very small way with only three or four men. The present owner now employs in the various departments of his great works, and in the coal and iron mines connected with them, 22,000 men, and one of the superintendents of the works informed us that these employees represented a population of more than 106,000 persons. He remarked that they were very rich in children. These works are not only the largest gun manufactory in the world, but are also extensive manufacturers of steel rails, steel tires for locomotives and car wheels; the best wheels used by the Canadian Pacific Railway and by the Pullman Company are made here. It would cover many pages to describe these great works. They are generally regarded as very difficult of access. In fact, very few people are able to get inside the works at all. We, however, found no trouble. Two superintendents of different parts of the works met us at the hotel and gave up two days showing us over as much of the great plant as we were able to travel in that time. The managers were somewhat reserved as to the manner in which they cast the great steel ingots from which the heavy cannons were made. In everything else they were quite willing to answer every question asked of them.

"From Essen I returned to London and the other members of the party after visiting other points returned to Paris and after a few days returned again to London. We then called upon the firm of Tennant & Sons, to whom the Sudbury people had been making shipments of matte. Sir Charles Tennant is president of the Steel Works of Scotland, of which Mr. James Riley is manager. He is the man who made the report

and the experiments with nickel and steel herewith enclosed. This firm told us they were ready to at once convert their steel works into a ferro-nickel plant if they could only obtain a supply of nickel, and were very anxious to obtain sole control of the output of the Sudbury mines. They said they had an order for 4,000 tons of ferro-nickel plates for a transatlantic steamship, but had no niekel with which to make them. This is the trouble with all these works, there is no nickel on the market to use in this alloy. Formerly the use of nickel has been very limited, the consumption of the world being only about one thousand tons per annum, nearly all of which has been used in the manufacture of German silver and coins, the new use in alloys makes



James Riley, Glasgow, Scotland, whose paper on Alloys of Nickel and Steel, read in May, 1889, before the Iron and Steel Institute of Great Britain, marked the beginning of the modern use of nickel as a constituent of high-class steel.

a great demand and finds the market without any supply. We were told in Paris that not ten tons of this metal could be had in the whole of Europe.

"Outside of Sudbury there is not at present produced more than 1,200 or 1,400 tons of nickel in the world and the French Government is using fully one-third of that amount in the manufacture of cartridge shells. If the Sudbury Company extend their works as purposed they will be producing ten times as much nickel as the other mines in the world. The utility of this alloy seems everywhere to be fully conceded and nothing seems to remain to bring it into important use but a sufficient supply of the material.

"From London we went to Swansea, which is the great copper, gold, silver and nickel smelting and refining centre of Europe. We stopped with Sir Hussy Vivian, who is the largest smelter in England and employs 3,000 men. He is treating a large amount of the Sudbury mattes and is so much pleased with them that he has purchased what is known as the Murray mine located upon the line of the Canadian Pacific Railway about three miles west of Sudbury, and is putting up a furnace at the mine

to smelt the ores and ship the matte to his works at Swansea to be refined. He expressed the highest opinion of these properties and a desire to be connected with them.

"Coming back from London we called at the office of the Rio Tinto Copper Mines. These mines are located on the southern coast of Spain about 30 miles in a direct line from the town of Huelva. The directors of this company invited us to go and visit them and we did so. These are the largest copper mines in Europe. They have been worked more or less for two thousand years, successively by Phoenicians, Romans, Goths, Huns, Moors and Spaniards, and now by an English company. They are very large deposits of low grade ore averaging only 2½ per cent. copper. We were very kindly entertained by the company upon our arrival and were shown their whole process. They mine about one and a half millions of tons per annum. Part of this is shipped to the sulphuric acid makers in England, Scotland and the United States, and the balance is either reduced to matte by smelting in the furnace upon the ground and the mattes sent to the company's refining furnaces near Swansea, or the copper is leached out of the ore after first being roasted and then precipitated upon iron. The company employ at the mine and at the refining works 12,000 men. They have a share and a bonded capital of $35,000,000, and in 1888 they paid a dividend of 17 per cent. upon their stock. Any description of the great establishments and mines visited beyond the mere outline given would exceed the limits of a report.

"From all the data we could obtain I was convinced that Sudbury could compete with any place in the world in the production of copper and that it could produce nickel for about one-half the price at which the French company could produce it. The best evidence I could obtain of the real importance of the Sudbury mines was the manifest desire both in England and upon the continent of the largest smelters, and consumers of both copper and nickel to become the owners of the mines or to control their output. Mr. Ritchie has furnished me with the most minute details of the expense of producing their material, and by comparing these figures with those published by the larger companies in Europe, I cannot escape the conclusion that this enterprise is one of the most important in Canada. Taking the three companies together I believe there are only two others which are likely to exceed them in importance, and they are Canada's two principal railway systems.

"I intended that my report should stop here, but Mr. Ritchie asked me to go with him to Birmingham and Sheffield, and I did so. At Birmingham we called upon Messrs. Henry Wiggin & Co. They and Sir Hussey Vivian, of Swansea, are the two principal nickel refiners in England, outside of those owned by the French company. They expresesd the strongest desire to become identified with the Sudbury company. They were the most frank and unreserved about the cost and manipulation of this metal in its refining processes of any people we had thus far met. They were also treating the Sudbury mattes while we were there. From Birmingham we went to Sheffield and visited the great crucible steel works of William Jessop & Sons. These works have been in operation for a hundred years and are probably the most famous for the high character of their steel of any works in the world. Their manager, M. J. F. Hall, has quietly for the last two years been experimenting with nickel as an alloy with steel, and has produced the most wonderful results. I was shown pieces of steel containing no more than five per cent. of nickel and only one inch square, which showed a tensile strength sufficient to lift and support two locomotives with their tenders. These are the most wonderful results ever obtained from steel in any form, so I am informed. A hundred pound gun is nearly completed by this firm for the British Government, and they told me they had orders for thousands of tons of this nickel steel but had no nickel with which to make it. The firm took much pains to show us everything connected with the process of producing this metal and answered unhesitatingly every question asked of them. Mr. Hall was not present when we were there but came to London the next day to see me, and he and Captain Buckingham, who represents the United States Navy, and Mr. Ritchie all met in my office. Mr.

Hall brought the samples with him from which such wonderful results were obtained, and gave Captain Buckingham and myself the fullest information regarding all his processes and results. The Captain declared that the success of such experiments would revolutionize the whole art of gun-making and the manufacture of armor plates. Mr. Hall said their whole operations were at a stand-still for want of nickel; but he had orders for many thousands of tons of this steel and could do nothing with them for lack of the nickel; that he could furnish any amount both to the Government and to individuals.

"Such being the conditions of the market for this metal, and Canada owning the governing supply of the world, I have asked myself, 'Why cannot Canada herself make this steel?'

"There is not a doubt that the best people in England would readily join in the enterprise. In answering this question the item of fuel at once comes up, and I learn upon inquiry that Chicago has the largest steel and rail mills in the United States. She hauls all her coke with which she reduces her ores and melts her pig iron, from Connellsville in Pennsylvania, a distance of over 500 miles. She also hauls her ores to her mills and furnaces from the mines in Michigan, a distance of over 400 miles. Canada can obtain coke from Pennsylvania at a haul of not more than 400 miles to the ores of Hastings county. A steel works located in this neighborhood would have the ores immediately at the place where they would be reduced. Why then should not Canada utilize these iron ores and these nickel ores and make this ferro-nickel upon her own territory? Why should she not go farther and make this nickel-steel and this armor-plate upon her own territory? If the Government takes the proper action there is no doubt that the best skill and the strongest financial backing in England could be had to carry it on, and it really looks as if it were possible for Canada to control the character and efficiency of the guns and the navies of the world. I am led to say this much from the statements of every expert with whom I have talked.

"The condition of the iron market here is unusually favorable for enlisting the necessary capital for an enterprise of this kind. The curious state of affairs is now presented here of iron being higher in England than in the United States. I enclose you slips from the papers showing the conditon of the market. Everywhere I have been on the Continent the same condition of the trade is found. I cannot but feel that it is Canada's golden opportunity to move and produce her own iron and steel as well as nickel steel for other countries. (Sgd.) Charles Tupper."

London, November, 1889.

Cost of Producing Matte in 1889

For use while in Europe, Mr. Ritchie had armed himself with analyses of the Sudbury ore and figures showing the cost of producing matte, etc. Among the statements was one dated September 1889, from Mr. H. P. McIntosh, secretary of the Canadian Copper Company, which is of interest as showing the cost of converting the nickel ore into matte at that time. Mr. McIntosh's letter reads:

"S. J. Ritchie, Esq., Care Morton Rose & Co., London, Eng. Dear Sir: In compliance with your telegram of this morning we enclose herewith assay report as follows: Mr. Hoffman's reports of March 16th and Oct. 1st 1885; Prof. Chapman's of Sept. 24th 1885; Orford Copper Co's reports, Dec. 1st, 2nd and 5th 1885; Sperry's certs. Nos. 2, 3 and 4, October 28th, 1885, and Nos. 7, 8 and 9, Nov. 9th, 1885; and his certs. Nov. 12th 1887, showing results of silver assay, samples of fifteen cars shipped to Nickol's Laurel Hill Works and complete analysis of copper ore. I have preserved no copy of the foregoing, and as they are the only record of the same, kindly preserve or have copies made.

"I also enclose a copy of the report of the Orford shipment, also reports of monthly assays for the Copper Cliff, Evans and Stobie up to the last inst.

"The itemized cost of matte is as follows:

Mining per ton	$2.79
Transporting	.255
Crushing and loading	.386
Cost of ore per ton at the roast heap	$3.431
Roasting per ton	.17
Delivering from R. H. to smelter	.28
Smelting per ton	1.76
This includes all fuel, labor, etc.	
Cost of one ton of ore in matte	$5.641

"The above figures are based on reports from the 1st of last Feb. to the 1st of last month, that is, six months, during which time the average run of the furnace was 6.87 tons of ore into one ton of matte.

"Multiplying $5.641 by 6.87 equals $38.75 per ton of matte. This cost is based on the working of one furnace to which all the fixed charges of smelting are charged; and now that we have got the two furnaces going the cost will probably be reduced to at least $35 per ton, and a greater number of furnaces will reduce it still lower than this, for there many of the fixed charges that will not be increased by the increase of the number of the furnaces, therefore the proportion of these charged to each ton of matte will decrease as the number of furnaces increase.

"The above remarks will also apply to the cost of producing the ore, for this cost includes many items of construction which will have to be duplicated, and besides as the production increases the fixed charges will not, therefore the amount of these per ton will decrease. We have calculated all of our figures against ourselves so as to have our factor of safety sufficiently large. Very respectfully, H. P. McIntosh, Sec'y."

"Frt. rate on shipment just leaving for Swansea: $9.13 Sudbury to Swansea; $7.51 Sudbury to Liverpool."

Mr. McArthur's Estimate of Costs

The possiblity of utilizing the ores of the northern nickel range has been considered by various parties ever since the range was brought to light, fifteen years ago, among others by Mr. Ritchie himself, who in 1903 carried on correspondence with Mr. James McArthur, formerly for many years general manager of the Canadian Copper Company, and superintendent of that company's works at Copper Cliff, on the probable cost of producing nickel-copper matte from the ore bodies of that range, based on his experience in the Sudbury region. Mr. Ritchie propounded a series of questions designed to cover the ground in a letter to Mr. McArthur dated 14th December, 1903, to which the latter made reply as follows:

"S. J. Ritchie, Esq., Dear Sir: I have carefully noted your favor of the 14th inst. with names, estimated extent of ore bodies, and analyses of the several properties therein mentioned, which taking the rough average of the 19 assays as shown, would give an average value 3.5 nickel and 1.5 copper. This is a better value than the Canadian Copper Co. could show if they bunched all their properties together for an average sampling and assaying, which would probably range round 2.5 nickel and 2.1 copper.

"Commencing with the mining costs, I herewith submit approximate cost for the mining and treatment of 600 tons ore per day, with a furnace concentration of seven into one, product 35 per cent. matte.

APPROXIMATE MINING COSTS

Men			
1	mine captain	$8 00	$ 8 00
200	miners, helpers, trammers, etc., average rate	1 80	360 00
20	rock house helpers, average rate	1 40	28 00
1	rock house foreman	2 00	2 00
1	clerk (time-keeper)	1 60	1 60
2	hoisting engineers	2 00	4 00
2	firemen	1 75	3 50
2	firemen helpers	1 40	2 80
229	men at an average rate	1 78	409 90
	or an average of 68 cents per ton of ore for labor.		
	Coal consumption, 15 tons at $5.50 (a high price)		82 50
	400 lbs. dynamite at 11c.		44 00
	Total cost for mining 600 tons ore		$536 40
	or total mining expense 89.4 cents per ton.		

MINING AND ROCK HOUSE PLANT

Estimated cost for an output of 600 tons daily.

1	rock house	$3,500 00	
1	crusher and engine	2,200 00	
2	mine skips	500 00	
12	mine machine drills	2,700 00	
12	mine hand cars one ton capacity	900 00	
1	mine blacksmith shop and tools	200 00	
1	boiler and compressor house	1,500 00	
3	100-h.p. boilers	9,000 00	
35,000	brick at $8.00 per M.	280 00	
	Mason work and mortar at $6.00 per M.	210 00	
1	compressor	4,000 00	
1	mine hoist	4,000 00	
15	log houses at $250.00 each	3,700 00	
1	log boarding house	2,000 00	
	Sundries, such as pumps, trunnels, sorting tables, wire ropes, etc.	2,000 00	
	Rough estimate for mining plant	$36,690 00	
	Carried mining costs		$536 40

ROAST YARD EXPENSE FOR ROASTING 600 TONS DAILY

Men			
32	at $1.40 unloading ore from cars, wheeling and building same on heaps for roasting		$44 80
7	at $1.40 laying out cordwood into the different beds and roasting the same		9 80
50	at $1.40 loading roasted ore on cars, blasting the same		70 00
1	foreman		2 00
90.	Labor item being 21c. per ton or		$126 60
	Roasting fuel for 600 tons ore, 15 cords wood at $2.00 per cord	$30 00	
	Blasting, 120 lbs. dynamite, 11c. per lb.	13 20	
			43 20

Fuel and dynamite being 7 1-5 cents per ton.	
Grand total for roasting, being 28 1-5 cents per ton, or in all	$169 80
Dwellings, 5 log houses at $250.00 each	1,250 00

COST OF SMELTING 600 TONS DAILY

Men	
4 feeders at $2.00	$ 8 00
18 charge wheelers, $1.75	31 50
18 pot wheelers, $1.75	31 50
2 toppers, $2.00	4 00
8 slag elevator men, $1.75	14 00
2 foremen, $2.25	4 50
4 inside laborers, $1.40	5 60
2 boiler firemen, $1.75	3 50
2 boiler firemen help, $1.50	3 00
2 engineers, $2.00	4 00
6 load, weigh and ship matte, $1.40	8 40
5 unloading foreign coke cars, $1.40	7 20
1 unloading foreign coal cars, $1.40	1 40
1 watchman	1 40
75. Total smelting labor 21⅓ cents per ton ore per day...	128 00

FUEL COST

84 tons coke at $7.00 per ton	$588 00
17 tons coal at $5.50 per ton	93 50
Total cost of fuel per ton ore smelted $1.13, or daily...	$681 50
Grand total for labor and fuel in smelting, $1.35 per ton ore	$809 50
Carried working costs:	
Mining	$536 40
Roasting	169 80
Smelting	809 50
	$1,515 70

Or total cost of all departments, being $2 55 per ton ore smelted.
Add for incidentals .... 20 " "

Giving a grand total of .... $2 75 " "

SMELTER MACHINERY

1 furnace building and bins	$5,000 00
1 600-ton furnace with equipments	10,000 00
1 No. 8 Connorsville blower	4,000 00
1 elevated water tank	1,600 00
1 granulating slag equipment	2,000 00
1 office and store house	300 00
1 laboratory	1,000 00
100,000 brick for chimney and dust chambers, at $8.00 per M.	800 00
Mason and mortar work at $6.00 per M.	600 00

1 boiler blowing engine house	1,500 00
3 100-h.p. boilers	9,000 00
1 pump, 1,000 gallons capacity	2,000 00
10 log houses at $250.00 each	2,500 00
1 boarding house	2,000 00

Fuel and dynamite being 7 1-5 cents per ton.	
Grand total for roasting, being 28 1-5 cents per ton, or in all	$169 80
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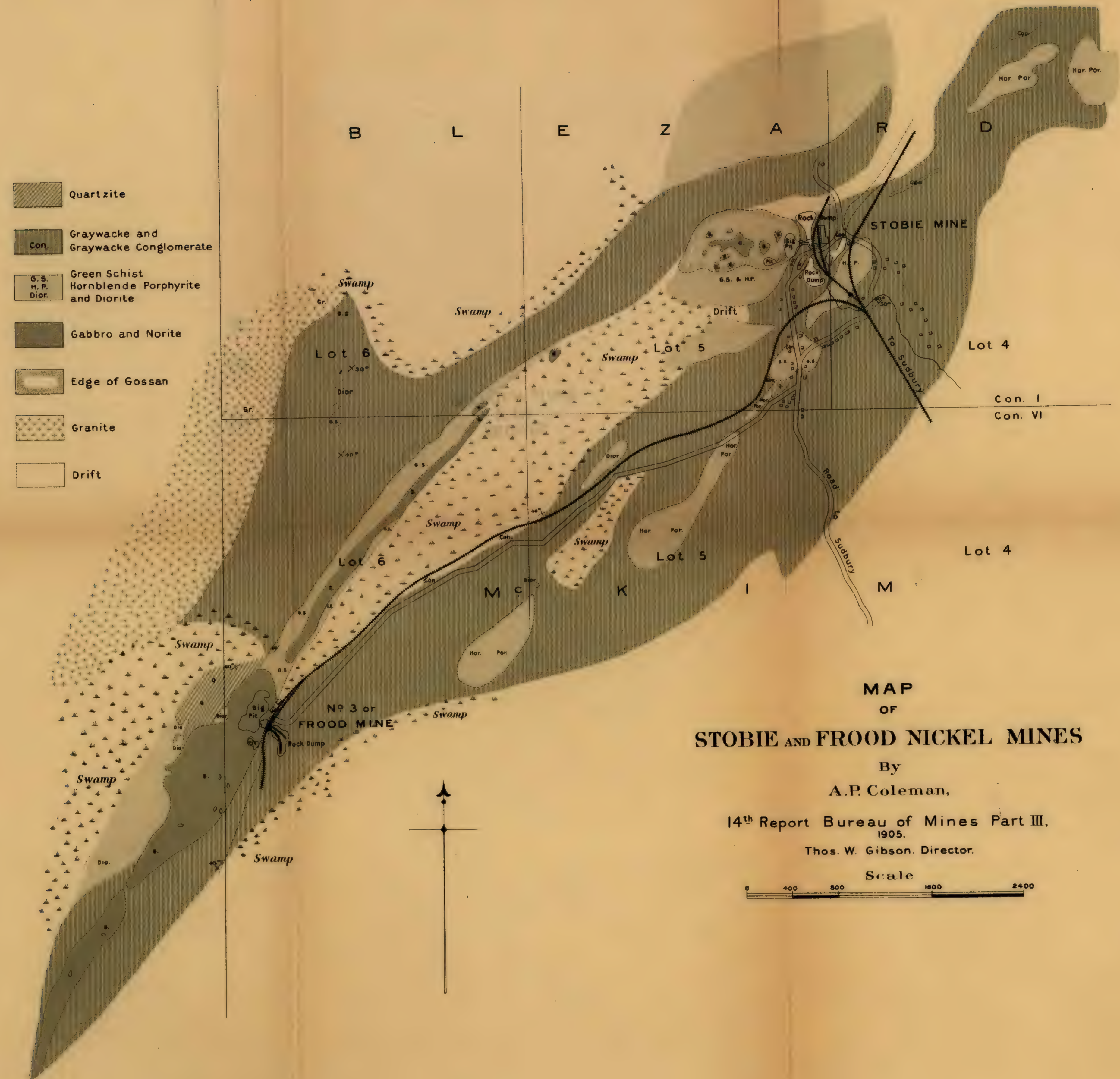
Quartzite
Con.
Graywacke and Graywacke Conglomerate
G.S. H.P. Dior.
Green Schist Hornblende Porphyrite and Diorite
Gabbro and Norite
Edge of Gossan
Granite
Drift
B L E Z A R D
STOBIE MINE
Rock Dump
Big Pit
Rock Dump
G.S. & H.P.
Drift
Hor. Por.
Hor. Por.
Lot 6
Lot 5
Lot 4
Swamp
To Sudbury
Con. I
Con. VI
Road to Sudbury
Lot 6
Lot 5
Lot 4
M^c K I M
Nº 3 or FROOD MINE
Big Pit
Rock Dump
MAP OF STOBIE AND FROOD NICKEL MINES
By A.P. Coleman,
14th Report Bureau of Mines Part III, 1905.
Thos. W. Gibson. Director.
Scale
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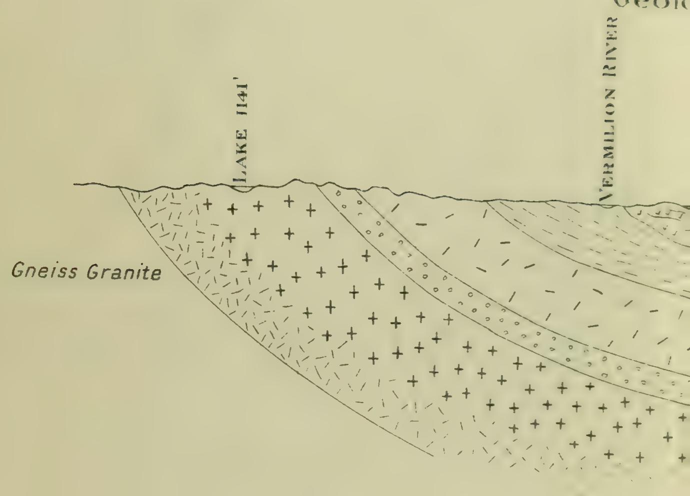
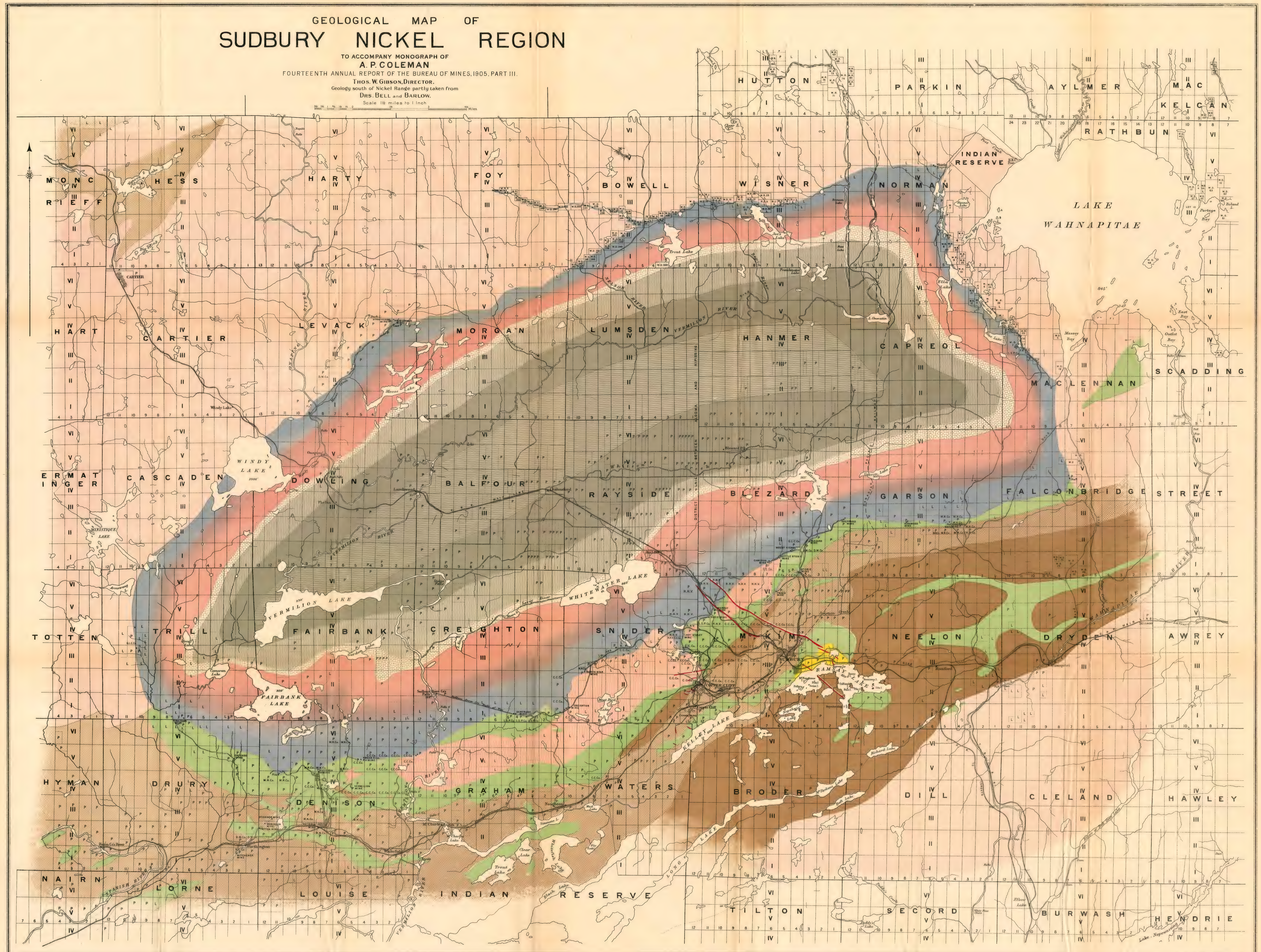
INDEX.

Geolo





Explanation of Colours and Signs.

Sedimentary Rocks

Upper Huronian - Animikie:
- Chelmsford Sandstone
- Onwatin Slate
- Onaping Tuff
- Trout Lake Conglomerate

Middle Huronian:
- Ramsay Lake Conglomerate

Lower Huronian:
- Quartzite
- Graywacke and Slate

Eruptive Rocks

Basic
- Diabase

Nickel Eruptive:
- Micropegmatite
- Norite

- Gabbro
- Older Norite
- Greenstone and Green Schist

Acid
- Granite (later than Nickel Eruption)
- Granite and Granitoid Gneiss (mostly Older)
- Laurentian (Granite and Gneiss younger than Huronian)

- Roads
- Railroads
- Rock Contacts
- P Land Patents
- L Land Leases
- C.C.Co. Canadian Copper Co.
- M.N.Co. Mond Nickel Co.
- L.S.P.Co. Lake Superior Power Co.
- \+ Gossan Showings

Geological Section across Nickel Basin.